

CAMBRIAN BRACHIOPODA FROM MONTANA

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CAMBRIAN BRACHIOPODA FROM MONTANA

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ABSTRACT.—This paper brings up to date, as nearly as is practicable, the systematic paleontology of the Cambrian brachiopods of Montana; records their occurrence in measured stratigraphic sections; and assigns to their proper stratigraphic positions, so far as is possible, the collections of brachiopods from Montana listed in Walcott's "Cambrian Brachiopoda," Monograph 51 of the United States Geological Survey. Forty-five species and one variety, of which 24 species and the variety are new, belonging to 20 genera, six new, are described and illustrated. Four more or less distinct brachiopod faunas occur in the Cambrian rocks of central and southern Montana: the lowest, characterized by *Prototreta flabellata* Bell, n. sp., is associated with the trilobite genus *Ehmania* near the base of the Middle Cambrian Meagher limestone; the next higher fauna, characterized by *Prototreta trapeza* Bell, occurs associated with the trilobite genus *Bathyriscus*, also in the lower Meagher limestone; the next higher fauna, characterized by *Dicellomus occidentalis* Bell, n. sp., occurs associated with the Upper Cambrian trilobite genera *Cedaria* and *Crepicephalus* in the upper Park shale and lower Pilgrim limestone; and the highest fauna, characterized by *Billingsella* and *Eoorthis*, occurs in the Dry Creek shale and its partial equivalent, the Snowy Range formation. *Dicellomus* Hall is shown to possess a normal atremate ventral pseudointerarea, the "pedicle tube" described by Walcott being an accident of preservation. Species which heretofore would have been assigned to *Acrotreta* Kutorga are described under four genera proposed by the writer. The genus *Dearbornia* Walcott is rejected, the genotype and only known species being assigned to *Acrothele* Linnarsson. *Wimanella* Walcott is shown to possess a smooth shell; the new genus *Diraphora* is proposed to include those costellate species that are similar internally to *Wimanella*. Species belonging to "*Lingulella*," *Lingulepis*, "*Obolus*," and *Westonia* are not included in this report.

PURPOSE OF INVESTIGATION

THE PURPOSE of this investigation is to bring up to date, as nearly as practicable, the systematic paleontology of the Cambrian brachiopods of Montana; to record their occurrence in measured stratigraphic sections; and to assign to their proper stratigraphic position, so far as possible, the collections of brachiopods from Montana listed in Monograph 51 of the United States Geological Survey. Species belonging to "*Lingulella*," *Lingulepis*, "*Obolus*," and *Westonia* are not included in this report.

The brachiopods that form the nucleus of this study were collected by field parties

under the direction of Professor Charles Deiss of Montana State University during his investigations of the Cambrian stratigraphy of northwestern and south-central Montana (Deiss, 1933, 1936, 1938, 1939a). A field party from the Museum of Paleontology, University of Michigan, collected Cambrian fossils at Beartooth Butte, Republic Mountain (Cooke), Pole Creek, and Nixon Gulch under the direction of the writer. The collections made by Deiss and the writer came from measured stratigraphic sections and form the standard with which prior, unzoned collections are compared. During January and February, 1939, the writer studied collections of Cambrian brachiopods from

Montana preserved in the U. S. National Museum and has redescribed and illustrated almost all the species whose type localities are in that State.

PREVIOUS WORK ON CAMBRIAN BRACHIOPODA FROM MONTANA AND YELLOWSTONE PARK

Meek (1873) was the first to describe brachiopods from the Cambrian rocks of Montana; he assigned them to the Potsdam, or Primordial zone of Silurian age. He (1873, p. 463) suggested that a species of *Acrotreta*, should it prove distinct from *A. subconica* Kutorga, be given the name *attenuata*. Meek (1873, p. 479) also described *Iphidea?? sculptilis*, and proposed the name *Micromitra* for it in the event that it should prove to "belong to an undefined genus, either of the Brachiopoda, or of some other group."

Walcott (1897, 1898, 1905, 1908a, 1912, 1924) described 15 new species of brachiopods from the Cambrian rocks of Montana and Yellowstone Park and recorded the occurrence of 22 additional species that had previously been described from other areas. No additions of new or previously described species to the Cambrian brachiopod fauna of Montana have been published since 1924. Thus 39 species of brachiopods belonging to 17 genera had been reported from the Cambrian of Montana and Yellowstone Park at the time this study was begun.

Schuchert and Cooper (1932) and Ulrich and Cooper (1938) published revisions of several genera and species that had been reported from Montana, but dealt with no species whose type locality occurs in the Cambrian rocks there with the exception of *Wimanelia simplex* Walcott.

ACKNOWLEDGMENTS

The writer is pleased to acknowledge his debt to those who have helped make this study possible. To Professor Charles Deiss of Montana State University for his loan of collections, direction and criticisms during study at the University, and continued encouragement and assistance during the later stages of the work, the writer is deeply grateful. To Dr. G. Arthur Cooper of the U. S. National Museum are due warmest thanks for his active support of the project from its beginning, assistance, advice, and criticism

during its progress, and for making possible an extended visit to the Museum in 1939. Professors G. M. Ehlers and E. C. Case of the University of Michigan have given material assistance in the form of research and collecting facilities, and encouragement and kindly criticism during the preparation of the manuscript; to them the writer is glad to express his thanks.

Acknowledgments are also due Professor Charles Schuchert of Yale University, Dr. Christina Lochman of Mount Holyoke College, Professor B. F. Howell of Princeton University, and Dr. Ira Edwards of Milwaukee Public Museum for information and for permission to examine the Cambrian brachiopods in their respective institutions. Mr. M. V. Denny of the University of Michigan gave valuable advice regarding photographic problems, and John A. Wilson and Robert M. Garrels of the same institution assisted during the collecting of fossils in 1937.

The completion of the work was facilitated by University of Michigan fellowships in the department of geology for the years 1937-38 and 1938-39.

PREPARATION OF MATERIAL

Ulrich and Cooper (1938, p. 2) have given a detailed description of methods useful in disclosing the interiors of brachiopod shells, and hence only a few comments are necessary here.

The only silicified shells in the writer's collections are specimens of *Billingsella* (pl. 35, figs. 1-18), *Eoorthis* (pl. 36, figs. 14-20), and *Ocnerorthis* (pl. 37, figs. 7, 10, 11) from Crowfoot Ridge, Yellowstone Park. They are readily freed of matrix by lowering them on a monel-metal screen into a dilute solution of hydrochloric acid. The unsilicified protrematous shells were prepared either by excavating the interiors with a needle (pl. 37, fig. 9), or by stripping away the shell in order to expose an impression of the interior (pl. 34, fig. 10; pl. 36, fig. 21). Excellent impressions of muscular and pallial markings in *Billingsella* and *Eoorthis* were uncovered in this way (pl. 34, fig. 12; pl. 36, fig. 23).

The study of the atrematous and neotrematous shells presented serious difficulties, primarily because of their small size (2.0-10.0 mm. in diameter). The shell sub-

stance, perhaps originally corneous, is now composed of calcite, and inasmuch as the valves almost invariably occur in crystalline or shaly limestones, chemical methods of preparation proved unsatisfactory. Exfoliation of the shell laminae exposed internal impressions in some valves (pl. 28, fig. 31; pl. 29, figs. 18, 19; pl. 30, fig. 31; pl. 31, fig. 33), but for others, particularly the ventral valves of the acrotretids, this method failed.

Excavation of the interiors by means of a needle, although inordinately slow, yielded the best results if the valves were imbedded in only a moderately resistant matrix. The interiors of *Prototreta trapeza* Bell represent the most successful results of this method (pl. 31, figs. 38-41, 45-48). In many instances, however, the combination of a thin-shelled fossil and a very resistant limestone matrix made this method impracticable.

As a last resort, serial sections (text figs. 1, 14, 15, 18-20) revealed the presence of internal structures that could not be uncovered by any other method. A simple device, intermediate in complexity between those described by Kozłowski (1932) and Simpson (1933, 1938), enabled the writer to make oriented sections 0.1 mm. apart. A drawing of each section was made on cross-section paper with the aid of an ocular grid, and from the completed series of drawings a reasonably accurate profile of any longitudinal structure could be constructed. This method, although indispensable at times, should be avoided whenever possible because it involves destruction of specimens, and because evidence resulting from it is often open to question. When little contrast in color exists between shell substance and matrix, difficulty is experienced in making accurate drawings. Serial sectioning can demonstrate the presence of structures in a shell at the time the section is made, but the absence of structures may be the result either of their never having been developed, or of their having been lost during the process of fossilization. The atrematous and neotrematous shells are so minute that broken edges, especially in distorted shells, cannot usually be distinguished from unbroken ones. Obviously, information regarding muscular and pallial markings cannot be obtained from serial sections.

MORPHOLOGY

GENERAL DISCUSSION

Charles D. Walcott was, without question, the foremost student of Cambrian Brachiopoda, as he was of all Cambrian faunas, during the first quarter of the present century. His monumental treatise, "Cambrian Brachiopoda," published as Monograph 51 of the U. S. Geological Survey (1912), will remain the foundation on which must be based all future studies dealing with these organisms.

References to Cambrian brachiopods since the termination of Walcott's work have for the most part been (1) investigations of a few genera by brachiopod specialists in order to determine their relationships to later stocks, and (2) proposals of new species by Cambrian students incidental to their investigation of the trilobites. Only the generic studies, which almost without exception deal with protrematous forms, have added essentially to our knowledge of the morphology and the systematic relationships of the Cambrian brachiopods. Consequently, at the time this study was begun, the state of knowledge regarding the inarticulate brachiopods was about as Walcott had left it.

The study of Cambrian stratigraphy has entered its logical second phase, that of revision of the earlier reconnaissance investigations. Trilobites, almost to the exclusion of other invertebrates, have been used for purposes of zoning and for interregional correlation. Besides being the most abundant element in most Cambrian faunas, trilobites lend themselves more readily to field determination than do the brachiopods and in the laboratory are more easily and quickly prepared for detailed study. As a result, the brachiopods have been almost entirely ignored by Cambrian workers.

The taxonomic importance of internal characters among brachiopods has been emphasized greatly by the comparatively recent studies of Buckman, Thomson, Cooper, Öpik, Kozłowski and others. Their investigations have revealed the pitfalls of homoeomorphy and polyphyletic development, pitfalls that trapped earlier workers who made identifications on the basis of external form alone. The lessons taught by these modern studies have not yet been applied to the Cambrian inarticulates, and conse-

quently the Cambrian stratigrapher is confronted by such "species" as *Iphidella pan-nula* and *Lingulella desiderata*, reported from Lower, Middle, and Upper Cambrian rocks and from localities as widely separated as British Columbia and Tennessee. No wonder Cambrian correlations based on evidence from brachiopods, especially the inarticulates, are regarded in some quarters as of doubtful value.

Six new genera, 24 new species, and one new variety are proposed in this paper. To some the number of new taxonomic units will seem excessive, particularly since they come from strata that have been known and studied as long as the Cambrian rocks of Montana. The writer, on the contrary, feels that he has been conservative, and that the study of better preserved and more abundant material will lead to the proposal of new species and genera that have been only hinted at in this paper. It may be that new species will be split from *Micromitra sculptilis*, *Icodonta nixonensis*, *Pegmatreta perplexa*, *Otusia sandbergi*, and *Eoorthis rem-nicha* as they are treated here, and that *Iphidella hexagona*, *Iphidella nyssa*, *Pegmatreta rotunda*, "*Acrotreta*" *tetonensis*, *Nisusia deissi*, and *Ocnerorthis monticola* will one day become genotypes. Whatever the verdict, it must be based on carefully prepared and abundant material from measured stratigraphic sections, probably in conjunction with additional material from regions other than Montana.

TERMINOLOGY

With the exceptions discussed below, the terminology used in this paper is, for the atrematous and neotrematous brachiopods, that used by Walcott (1912, pp. 292-296), and for the protrematous forms, that used by Schuchert and Cooper (1932, pp. 6-11).

Pseudointerarea.—In their discussion of the interarea, Schuchert and Cooper (1932, p. 20) say:

Interareas, or what were formerly called cardinal areas, are usual in most of the members of the order Protremata and especially in its most primitive stock, the Orthoidea. True interareas are at times also well developed in the Telotremata, but never in the Atremata and Neotremata. When a similar structure is present in the two last named orders it is due to holoperipheral growth or the subsequent internal thickenings of the posterior

margins, and in both these instances it is termed a pseudointerarea.

The term pseudointerarea is applied by the writer to the posterior slope of the subconical ventral valve in the neotremates and in the *Micromitra-Paterina-Iphidella* group of species, and to the flattened surfaces usually characterizing the thickened posterior margins of the dorsal valve in many neotremates and both valves in the atremates. The pseudointerarea may or may not be differentiated into propareas (q.v.).

Schuchert and Cooper's (1932, p. 20) system for describing the orientation of the interarea and pseudointerarea is followed by the present writer. However, it is not clear from their discussion how the degree of proclination or hyperclination of an interarea should be described. In this paper the degree of proclination or hyperclination is read from the vertical. Thus, in a subconical ventral valve in which the posterior slope is nearly vertical, the pseudointerarea is described as being slightly procline, or the amount of proclination may be given in degrees of arc. The orthocline position is considered to be basic, and the inclination of the interarea or pseudointerarea diverges from it either in a clockwise or counterclockwise direction. Thus, in a ventral valve, as the interarea or pseudointerarea is rotated in a counterclockwise direction from the orthocline position, its orientation becomes progressively slightly apsacline, strongly apsacline, catacline, slightly procline, and, finally, strongly procline.

Proparea (emended from Bell, 1938, p. 405).—This term is applied to each of the two smooth subtriangular surfaces that border the delthyrium and notothyrium in many of the *Micromitra-Paterina-Iphidella* group, and which are delimited from the rest of the valve by ridges or grooves (pl. 28, figs. 3, 4, 6, 15, 25, 26). *Proparea* is also applied to each subtriangular half of the pseudointerarea, as it is developed in the neotremate dorsal and the atremate ventral valve, when the pseudointerarea is divided medially by a groove. Propareas are characteristic of the dorsal valve of certain neotremates, such as *Prototreta* (pl. 31, figs. 44-48) and *Homotreta* (pl. 30, fig. 31), and are separated by a triangular depression, which is thought to serve as a seat of muscular at-

tachment. In the linguloids and oboloids the propareas, typically developed only in the ventral valve, are separated by the pedicle groove. The term proparea is proposed for convenience in description and does not imply that the structures so designated are of similar origin.

Intertrough.—This term is proposed to designate the furrow, called "false pedicle groove" by Walcott (1912, p. 675), which characterizes the ventral pseudointerarea in certain neotremate species. The furrow, especially well developed in *Prototreta* (pl. 31, fig. 34), is deeper and wider at the commissure than at the apex of the valve. In most specimens the floor of the furrow is somewhat flattened and granular. Almost certainly the intertrough was genetically unrelated to the functional pedicle, and hence the term "false pedicle groove," which Walcott used freely but apparently never defined, seems inappropriate.

Delthyrium and *notothyrium*.—These terms are used for the triangular openings, serving as a passage for the pedicle, in the ventral and dorsal pseudointerareas, respectively, of the *Micromitra-Paterina-Iphidella* group of species. Inasmuch as the openings are certainly analogous and perhaps homologous to the pedicle openings in the Protremata, nothing is gained by the use of such terms as pseudodelthyrium or pedicle notch.

Homoeodeltidium and *homoeochilidium*.—Thomson (1927, pp. 64–68) analyzed the various usages of the terms *deltidium*, *pseudodeltidium*, and *homoeodeltidium*, and concluded that the term *homoeodeltidium*, proposed by Schuchert (in Zittel, 1913, Textbook of Paleontology, p. 358), should be applied to "a convex structure on the outer surface of the ventral valve of certain Neotremata along the area of pedicle-pressure between the apex and the pedicle-notch, not delimited from the rest of the valve by grooves." Thomson was referring to the deltidium-like plate occurring in many of the *Micromitra-Paterina-Iphidella* group, which he classified under the Neotremata. The writer follows Schuchert and Thomson in the use of *homoeodeltidium*, in place of which Walcott substituted *pseudodeltidium*, a term originally proposed by Bronn in 1862 for the single plate covering the delthyrium in the Protremata (*deltidium* of most American

authors). Eventually the discordance between European and American writers in the use of *deltidium*, *pseudodeltidium*, etc. must be settled, but in this paper the writer follows Schuchert and Cooper in the protremate nomenclature. *Homoeochilidium* (*pseudochilidium* of Walcott) is used in this paper as a companion term for *homoeodeltidium* to denote the similar plate present in the dorsal valve of the *Micromitra-Paterina-Iphidella* group, this structure being analogous to the chilidium in the Protremata.

HOMOEOMORPHY

A single instance of isochronous homoeomorphy is noted in this paper. *Prototreta flabellata* Bell, n. sp. (pl. 31, figs. 49–58) and *Homotreta interrupta* Bell, n. sp. (pl. 30, figs. 19–26) are strikingly similar externally, even to minutiae of surface ornamentation (compare pl. 30, fig. 25 with pl. 31, fig. 57). The segmentation of the fila in *Homotreta interrupta* is more commonly and more regularly developed than it is in *Prototreta flabellata*, but some valves of the two species are indistinguishable from the exterior (compare pl. 30, fig. 22 with pl. 31, figs. 53 and 55). Internally the two species are also remarkably similar but differ distinctly and consistently in the configuration of the dorsal septum (compare pl. 30, figs. 19, 26 and text fig. 1 with pl. 31, fig. 56 and text fig. 20). This difference is considered by the writer to be of generic value.

Prototreta flabellata is confined to the *Ehmania* zone of the Meagher limestone in central and south-central Montana and Yellowstone Park, and *Homotreta interrupta* is confined to the nearly contemporaneous northern phase of the Pagoda limestone, also characterized by the trilobite genus *Ehmania*, as it is developed at Lick Creek and Pentagon Mountain in northwestern Montana.

STRATIGRAPHY

Although this paper is intended to be strictly paleontologic, the stratigraphic evidence given by the fossils not being analyzed at this time, a brief summary of the rock sequence within the Cambrian of Montana and adjacent areas to the south is necessary.

Deiss (1939a) has divided the Cambrian rocks of northwestern Montana, from the

base upward, into the Flathead sandstone, Gordon shale, Damnation limestone, Dearborn limestone, Pagoda limestone,¹ Pentagon shale, Steamboat limestone, Switchback shale, and Devils Glen dolomite. These formations are all considered to be of Middle Cambrian age. Brachiopods collected from the Gordon shale, Damnation limestone, Pagoda limestone, and Pentagon shale are discussed in this paper.

In a recent paper by Deiss (1936) the Cambrian sequence in central and south-central Montana and Yellowstone Park is given, from the base upward, as the Flathead sandstone, Wolsey shale, Meagher limestone, Park shale, Pilgrim limestone, and Dry Creek shale. The Middle-Upper Cambrian boundary has not been definitely located, but it occurs somewhere within the Park shale. The Park shale is typically barren of fossils, but at a few localities carries an Upper Cambrian fauna in its upper part. Every formation except the Flathead sandstone has yielded brachiopods discussed in this paper.

Dorf and Lochman (1940) have proposed three new formational units for the Upper Cambrian strata of southern Montana (specifically, around the Beartooth Range). These are, from the base upward, the Maurice (Dresbach equivalent), Snowy Range (Franconia equivalent), and Grove Creek (Trempealeau equivalent) formations. Brachiopods discussed in this paper were collected from the Snowy Range formation at Beartooth Butte, Republic Mountain (Cooke), and Torrey Creek.

Dorf and Lochman (1940, p. 551) would transfer the Crowfoot Ridge section (Deiss, 1936, p. 1318) from the central Montana basin to the southern Montana basin. According to them "the unit called the Pilgrim by Deiss is the Maurice formation, and that termed the Dry Creek shale apparently represents the lower portion of the Snowy Range formation."

¹ The Pagoda limestone at localities 11-2, 30-2, and 51-1 (type locality) is characterized by a *Glyphaspis* fauna; but the "Pagoda" limestone at localities 26-2, 26-3, and 28-1, where it underlies the Pentagon shale (carrying a *Bathyriscus* fauna), is characterized by an *Ehmania* fauna. At Nixon Gulch, in south-central Montana, the *Glyphaspis* zone of the Wolsey shale underlies and is distinct from the *Ehmania* zone of the basal Meagher limestone.

REGISTER OF FOSSIL LOCALITIES

The following register gives the geographic location of the fossil localities from which the species discussed in this paper were collected and the names of the species from each locality. New species are listed without the author's name.

MONTANA STATE UNIVERSITY LOCALITIES

6. Continental Divide, Lewis and Clark Range, about 2 miles southeast of Pentagon Mountain (Deiss, 1938, p. 1075; 1939a, p. 64).
Zone 2, Pentagon shale (type locality): 30 to 35 feet above base.
Micromitra sculptilis (Meek)
Pegmatreta perplexa
Prototreta subcircularis
9. Flathead Range, on the southwest side and near the top of Pagoda Mountain (Deiss, 1939a, pp. 14, 64).
Zone 2, Damnation limestone: lower part.
Iphidella cf. *I. nyssa* Walcott
11. Canyon of North Fork of Dearborn River, Lewis and Clark Range, Coopers Lake quadrangle (Deiss, 1939a, pp. 33, 64).
Zone 2, Pagoda limestone: near water level.
Icodonta? cf. *I. nixonensis*
Iphidella hexagona
20. Continental Divide, crest of Lewis and Clark Range, Coopers Lake quadrangle, west end of Scapegoat Basin at foot of cliffs (Deiss, 1938, p. 1087; 1939a, p. 65).
Zone 1c, Gordon shale: about 20 feet below top.
Wimanella simplex Walcott
Zone 2, Damnation limestone (type locality): basal 25 feet.
Nisusia sp. 1
Nisusia sp. 2
23. Continental Divide, Lewis and Clark Range, south side of Bench Mark 8105 Peak, head of Ahorn Creek, Ovando quadrangle (Deiss, 1939a, p. 65).
Zone 1, Gordon shale: upper part.
Iphidella nyssa Walcott
Wimanella simplex Walcott
26. Continental Divide, Lewis and Clark Range, above head of south fork of

- Lick Creek (Deiss, 1939a, pp. 16, 17, 66).
- Zone 2, "Pagoda" limestone: 52 feet below top.
Homotreta interrupta
Pegmatreta perplexa
Pegmatreta rotunda
- Zone 3, "Pagoda" limestone: 35 feet above zone 2.
Homotreta interrupta
Micromitra sculptilis (Meek)
Pegmatreta perplexa
Pegmatreta rotunda
- Zone 4, Pentagon shale: 34 feet above base.
Acrothele pentagonensis
Micromitra sculptilis (Meek)
Micromitra? subdita
Pegmatreta perplexa
Prototreta subcircularis
Prototreta trapeza Bell
- Zone "loose," Pentagon shale: specimens restricted to lower half of formation, but exact stratigraphic horizon unknown.
Nisusia lickensis
- Zone "top," Pentagon shale: 110 feet above zone 4. Fossils collected in place, but from an interval 45 feet thick.
Prototreta cf. *P. trapeza* Bell
Nisusia lickensis
28. Lewis and Clark Range, ridge between Rock and Baldy Bear Creeks (Deiss, 1939a, pp. 19, 66).
 Zone 1, "Pagoda" limestone: 41 feet below top.
Homotreta interrupta
Nisusia deissi
- Zone "loose," "Pagoda" limestone: specimens not collected in place, but restricted to within 20 feet stratigraphically above zone 1.
Micromitra cf. *M. sculptilis* (Meek)
Nisusia montanaensis
30. Continental Divide, Lewis and Clark Range, Chinese Wall, Cliff Mountain (Deiss, 1939a, pp. 22, 67).
 Zone 2, Pagoda limestone.
Iphidella hexagona
31. Little Belt Mountains, Belt Creek valley, gulch half a mile east of Hoover Creek (Deiss, 1936, p. 1271).
 Zone 1, Wolsey shale: thin limestones interbedded in upper part.
Nisusia cf. *N. deissi*
32. Little Belt Mountains, north side of Belt Creek valley, 3 to 5 miles southeast of Monarch (Deiss, 1936, p. 1269).
 Zone 3, Pilgrim limestone: lower part.
Dicellomus occidentalis
33. Little Belt Mountains, south end of Keegan Butte in Belt Park on south side of Belt Creek, about 2 miles east of Monarch (Deiss, 1936, p. 1274).
 Zone 1, Pilgrim limestone: about 33 feet below top.
Dicellomus cf. *D. occidentalis*
 Zone 2, Pilgrim limestone: basal few feet.
Dicellomus occidentalis
 Zone 3, Wolsey shale: interbedded lenticular limestone from lower (L) and upper (U) parts of shale slope.
Icodonta typica
34. Little Belt Mountains, South Hill, immediately south of Keegan Butte (Deiss, 1936, p. 1276).
 Zone 5U, Wolsey shale: interbedded lenticular limestone from upper part of shale slope.
Micromitra sculptilis (Meek)
Nisusia cf. *N. deissi*
38. Little Belt Mountains, north slope of Dry Wolf Creek valley, about 2 miles above its junction with Lion Gulch (Deiss, 1936, p. 1279).
 Zone 1, Park shale: limestone lenses throughout upper 175 feet.
Dicellomus occidentalis
 Zone 3, Pilgrim limestone: about 300 feet above base.
Dicellomus occidentalis
 Zone 4, Pilgrim limestone: about 20 feet above zone 3.
Dicellomus sp.
 Zone 5, Pilgrim limestone: about 20 feet above zone 4.
Dicellomus sp.
39. Little Belt Mountains, north side of Yogo Gulch immediately west of the mouth of Bear Creek (Deiss, 1936, p. 1283).

- Zone 1, Dry Creek shale: about 10 feet above base.
Eoorthis cf. *E. remnicha* (Winchell)
40. Big Snowy Mountains, head of Swimming Woman Creek (Deiss, 1936, p. 1290).
 Zone 2, Wolsey shale: about 120 feet above base.
Icodonta nixonensis
Wimanella auralis
41. Big Snowy Mountains, head of Swimming Woman Creek (Deiss, 1936, p. 1290).
 Zone 3, Park shale: about 30 feet below top.
Dicellomus occidentalis
42. Castle Mountains, north side of Checkerboard Creek (Deiss, 1936, p. 1286).
 Zone 2, Meagher limestone: about 50 feet above base.
Schuchertina cf. *S. cambria* Walcott
43. Gallatin Range, northwest spur of Crowfoot Ridge, Yellowstone National Park (Deiss, 1936, p. 1318).
 Zone 3, Meagher limestone: *Ehmania* zone, about 37 feet above base.
Nisusia deissi
 Zone 3a, Meagher limestone: limestone nodules in 3-5 ft. shale bed, immediately overlying zone 3.
Prototreta flabellata
44. Gallatin Range, northwest spur of Crowfoot Ridge, Yellowstone National Park (Deiss, 1936, p. 1318).
 Zone 2, Dry Creek shale: upper 60 feet.
"Acrotreta" tetonensis Walcott
Billingsella cf. *B. alata*
Billingsella exasperata
Billingsella perfecta Ulrich and Cooper
Billingsella perfecta pyriformis
Billingsella radiata
Dicellomus mosaica
Eoorthis remnicha (Winchell)
Linnarssonella elongata
Ocnerorthis monticola
45. Horseshoe Hills, on both sides of Nixon Gulch, about 6 miles north of Manhattan, Three Forks quadrangle (Deiss, 1936, p. 1311).
 Zone 1, Wolsey shale: middle part of chocolate and green shale on Trilobite Hill (equivalent of Mich. M4-1 and M4-2).
Icodonta nixonensis
Wimanella auralis
 Zone 2, Meagher limestone: *Ehmania* zone, at base of formation, on Trilobite Hill (equivalent of Mich. M4-3).
Micromitra sculptilis (Meek)
Prototreta flabellata
 Zone 3, Meagher limestone: *Bathyriscus* zone, 20 feet above zone 2, on Trilobite Hill (equivalent of Mich. M4-4).
Micromitra sculptilis (Meek)
Micromitra? subdita
Pegmatreta perplexa
Prototreta subcircularis
Prototreta trapeza Bell
 Zone 3a, Meagher limestone: *Bathyriscus* zone, 1500 feet N. 12° W. from zone 3 (equivalent of Mich. M4-4a and U.S.N.M. loc. 19z).
 Same fauna as zone 3.
46. Horseshoe Hills, on both sides of Nixon Gulch, about 7 miles north of Manhattan, Three Forks quadrangle (Deiss, 1936, p. 1311).
 Zone 3, Dry Creek shale: about 20 feet above base.
"Acrotreta" tetonensis Walcott
Billingsella alata
Billingsella cf. *B. exasperata*
Billingsella perfecta Ulrich and Cooper
Billingsella plicatella Walcott
Ceratreta hebes
Dicellomus mosaica
Eoorthis remnicha (Winchell)
Huenella abnormis (Walcott)
Otusia sandbergi (Winchell)
47. Big Belt Mountains, north side of Beaver Creek, opposite schoolhouse about 2 miles downstream from Nelson (Deiss, 1936, p. 1295).
 Zone 2, Meagher limestone: basal bed lying on Wolsey shale.
Diraphora? sp.
 Zone 2T, Meagher limestone: fossiliferous bed 8 feet above zone 2.
Micromitra sculptilis (Meek)

Zone 3, Meagher limestone: $\frac{1}{2}$ to 2 inch layer of black fissile shale, 3 feet above zone 2T, with intercalated limestone nodules.

Micromitra cf. *M. sculptilis* (Meek)

Pegmatreta perplexa

Prototreta mimica

Zone 3 "loose," lower Meagher limestone talus.

Prototreta trapeza Bell

51. Prairie Reef Mountain, Lewis and Clark Range, southeastern part of Silvertip quadrangle (Deiss, 1938, p. 1080; 1939a, p. 67).

Zone 1, Pagoda limestone (type locality): about 100 feet above base.

Iphidella hexagona

53. Kid Mountain, Swan Range, between Gordon and Youngs Creeks Ovando quadrangle (Deiss, 1939a, pp. 10, 68).

Zone 1, Gordon shale: about 70 feet below top.

Iphidella nyssa Walcott

Wimanelia cf. *W. simplex* Walcott

University of Michigan Localities

- M1. East face of Beartooth Butte, Beartooth Mountains, Wyoming, below north end of Bighorn dolomite cliffs (Dorf, 1934, pp. 721-726).

Zone 4, Snowy Range formation: *Conaspis* zone, in lower third of formation and immediately overlying *Collenia magna* zone (Fenton, 1939, p. 97).

"*Acrotreta*" *tetonensis* Walcott

Billingsella alata

Billingsella exasperata

Billingsella perfecta Ulrich and Cooper

Billingsella radiata

Ceratreta hebes

Dicellomus mosaica

Eoorthis remnicha (Winchell)

Linnarssonella elongata

Otusia sandbergi (Winchell)

- M2. Northeast nose of Republic Mountain, above old Republic smelter, Cooke, Montana (Lovering, 1929, p. 23).

Zone 1, Snowy Range formation:

Conaspis zone, immediately overlying *Collenia magna* zone.

Billingsella perfecta Ulrich and Cooper

Billingsella plicatella Walcott

Billingsella radiata

Ceratreta hebes

Dicellomus mosaica

Eoorthis remnicha (Winchell)

- M3. North slope of Pole Creek valley, about 1.5 miles upstream from its junction with Cherry Creek, Three Forks quadrangle.

Zone 1, Meagher limestone: a 13-ft. interval of platy and nodular limestone, 40 feet above base of formation; part of *Ehmania* zone (equivalent of U.S.N.M. loc. 20k).

Iphidella hexagona

Micromitra sculptilis (Meek)

Nisusia deissi

Nisusia montanaensis

Zone 2, Meagher limestone: a 13-ft. interval of fissile black shale with intercalated limestone nodules, about 68 feet above base of formation; part of *Ehmania* zone.

Micromitra sculptilis (Meek)

Prototreta flabellata

- M4. Same as Montana locality 45.

Zone 1, Wolsey shale: lower or *Zacanthoides* zone of Mont. loc. 45-1.

Icodonta nixonensis

Zone 3, Meagher limestone: equivalent of Mont. loc. 45-2.

Micromitra sculptilis (Meek)

Prototreta flabellata

Zone 4, Meagher limestone: equivalent of Mont. loc. 45-3.

Micromitra sculptilis (Meek)

Micromitra? *subdita*

Pegmatreta perplexa

Prototreta subcircularis

Prototreta trapeza Bell

Zone 4a, Meagher limestone: equivalent of Mont. loc. 45-3a and U.S.N.M. loc. 19z.

Same fauna as zone 4.

U.S. NATIONAL MUSEUM LOCALITIES²

- 4e. Dry Creek shale: head of Jackson

² See U. S. Geol. Survey, Mon. 51, pp. 160-291 for detailed descriptions of localities.

Creek, Teton Mountains, Grand Teton quadrangle, Uinta County, Wyoming.

"Acrotreta" tetonensis Walcott

Billingsella perfecta Ulrich and Cooper

- 4h. Meagher limestone: 4 miles east-northeast of Logan, Three Forks quadrangle.

Micromitra sculptilis (Meek)

- 4j. Dry Creek shale: head of Deep Creek, Canyon quadrangle, Yellowstone Park.

Billingsella alata

Billingsella exasperata

Billingsella plicatella Walcott

Huenella abnormis (Walcott)

- 4n. Meagher limestone (*Ehmania* zone): head of Jackson Creek, Teton Mountains, Grand Teton quadrangle, Uinta County, Wyoming.

Prototreta flabellata

- 4o. Meagher limestone (*Bathyriscus* zone): head of Jackson Creek, Teton Mountains, Grand Teton quadrangle, Uinta County, Wyoming.

Prototreta trapeza Bell

- 4p. Meagher limestone: 2 miles northeast of Logan, Three Forks quadrangle.

Micromitra cf. *M. sculptilis* (Meek)

- 4q. Gordon shale: ridge between Gordon and Youngs Creeks, Ovando quadrangle.

Acrothele colleni Walcott

Iphidella nyssa Walcott

Wimanella simplex Walcott

- 4r. Dry Creek shale: 3 miles north-northeast of Mount Delano, Livingston quadrangle.

Eoorthis remnicha (Winchell)

- 4v. Gordon shale: Gordon Creek, 6 miles from South Fork of Flathead River, Ovando quadrangle.

Acrothele panderi Walcott

Iphidella nyssa Walcott

Wimanella simplex Walcott

- 4w. Gordon shale: Youngs Creek, 5 miles from its junction with Danaher Creek, Ovando quadrangle.

Wimanella simplex Walcott

- 4x. Wolsey shale (interbedded limestone): base of butte in Belt Park,

about 6 miles northwest of Neihart, Little Belt Mountains quadrangle.

Micromitra sculptilis (Meek)

- 5f. Wolsey shale (interbedded limestone): head of Sawmill Creek, 11 miles south of Neihart, Little Belt Mountains quadrangle.

Micromitra sculptilis (Meek)

Nisusia cf. *N. deissi*

- 5j. Gordon shale: about 6 miles west-northwest of Scapegoat Mountain, Coopers Lake quadrangle.

Acrothele panderi Walcott

- 5k. (1) Meagher limestone, and (2) limestone lenses in Park shale: head of Sawmill Creek, 8 miles south of Neihart, Little Belt Mountains quadrangle. (Original label gives 13 miles south of Neihart).

(1) *Micromitra sculptilis* (Meek)

(1) *Nisusia* cf. *N. deissi*

(1) *Schuchertina cambria* Walcott

(2) *Dicellomus occidentalis*

- 9h. Meagher limestone (*Ehmania* zone): Beaver Creek, 5 miles north of York, Big Belt Mountains, Fort Logan quadrangle.

Diraphora? sp.

Micromitra sculptilis (Meek)

Prototreta flabellata

- 9k. Middle Cambrian: limestone forming 1c of the Dearborn River section (Walcott, 1908b, p. 201), on North Fork of Dearborn River, in the eastern part of the Lewis and Clark National Forest, Lewis and Clark County. (Stratigraphic position unknown; possibly Damnation limestone.)

Acrothele clarki (Walcott)

- 19z. Meagher limestone (*Bathyriscus* zone): Nixon Gulch, Three Forks quadrangle (equivalent of Mont. 45-3a and Mich. M4-4a).

Prototreta trapeza Bell

- 20k. Meagher limestone (*Ehmania* zone): Pole Creek, Three Forks quadrangle (equivalent of Mich. M3-1).

Iphidella hexagona

Nisusia deissi

Nisusia montanaensis

- 54z. Wolsey shale: Big Snowy Mountains (probably equivalent of Mont. 40-2).

Wimanella auralis

- 62r. Dry Creek shale: Abiather Mountain, Yellowstone Park.
Billingsella exasperata
Billingsella perfecta Ulrich and Cooper
- 147a. Dry Creek shale: Spring Hill Canyon, west side of Bridger Range, Gallatin County.
Billingsella exasperata
- 149a. Meagher limestone: forks of Pole Creek, above Cherry Creek basin, Three Forks quadrangle.
Diraphora striata (Walcott)
Iphidella cf. *I. hexagona*
- 150a. Dry Creek shale: about 5 miles north of Hillsdale, Three Forks quadrangle.
Billingsella exasperata
Billingsella plicatella Walcott
151. Dry Creek shale: point overlooking Churn Canyon, west side of Bridger Range, Gallatin County.
Billingsella exasperata
Billingsella plicatella Walcott
Eoorthis remnicha (Winchell)
- 151a. Dry Creek shale: point overlooking Churn Canyon, west side of Bridger Range, Gallatin County.
Billingsella cf. *B. plicatella* Walcott
Dicellomus mosaica
- 151e. Dry Creek shale: Soda Butte Creek, Yellowstone Park.
Billingsella perfecta Ulrich and Cooper
152. Dry Creek shale: ridge between Churn and Cottonwood Canyons, west side of Bridger Range, Gallatin County.
Billingsella exasperata
Billingsella plicatella Walcott
Eoorthis remnicha (Winchell)
- 152a. Dry Creek shale: west side of Dry Creek, below Pass Creek, Three Forks quadrangle.
Dicellomus mosaica
153. Dry Creek shale: 5 miles north of Hillsdale, Three Forks quadrangle.
Billingsella plicatella Walcott
Huenella abnormis (Walcott)
- 153a. Dry Creek shale: about 5 miles north of Hillsdale, Three Forks quadrangle.
Billingsella cf. *B. plicatella* Walcott
Eoorthis remnicha (Winchell)
154. Dry Creek shale: about 5 miles north of Hillsdale, Three Forks quadrangle.
Billingsella perfecta Ulrich and Cooper
Billingsella plicatella Walcott
Eoorthis remnicha (Winchell)
- 155a. Meagher limestone (*Bathyuriscus* zone): near Hillsdale, Three Forks quadrangle.
Micromitra sculptilis (Meek)
Micromitra? subdita
- 156a. Meagher limestone (*Ehmania* zone): near Hillsdale, Three Forks quadrangle.
Prototreta flabellata
- 156b. Dry Creek shale: north end of Gallatin Valley, Three Forks quadrangle.
Billingsella plicatella Walcott
157. Dry Creek shale: near Hillsdale, Three Forks quadrangle.
Billingsella plicatella Walcott
Huenella abnormis (Walcott)
158. Dry Creek shale: near Hillsdale, Three Forks quadrangle.
Billingsella exasperata
Billingsella plicatella Walcott
Dicellomus mosaica
Eoorthis remnicha (Winchell)
Huenella abnormis (Walcott)
159. Meagher limestone (*Ehmania* zone): north of West Gallatin (Gallatin) River, Gallatin County.
Diraphora? sp.
Micromitra sculptilis (Meek)
Nisusia cf. *N. montanaensis*
Prototreta flabellata
302. Meagher limestone (*Ehmania* zone?): east of West Gallatin (Gallatin) River, above Gallatin, Gallatin County.
Micromitra sculptilis (Meek)
Prototreta attenuata (Meek)
- 302b. (1) Meagher limestone and (2) Dry Creek shale: near Crowfoot Ridge, Gallatin quadrangle, Yellowstone Park.
(1) *Micromitra sculptilis* (Meek)
(2) *Eoorthis remnicha* (Winchell)
- 302c. Dry Creek shale: south side of Gallatin Valley, Yellowstone Park.
Ocnorthis? iddingsi (Walcott)
- 302f. Dry Creek shale: north side of Elk Pass, between Buffalo and Slough Creeks, Yellowstone Park.

- Billingsella exasperata*
Eoorthis remnicha (Winchell)
Otusia sandbergi (Winchell)
- 302g. Dry Creek shale: north slope of Crowfoot Ridge, Gallatin quadrangle, Yellowstone Park.
Billingsella cf. *B. exasperata*
Billingsella perfecta Ulrich and Cooper
Billingsella perfecta pyriformis
Billingsella weedi (Walcott)
Huenella abnormis (Walcott)
- 302k. Limestone in upper Park shale (?): near Gallatin, Three Forks quadrangle.
Dicellomus occidentalis
- 302n. Dry Creek shale: south side of Gallatin Valley, Gallatin County.
Eoorthis remnicha (Winchell)
- 302r. Dry Creek shale: near Princeton, Philipsburg quadrangle.
Billingsella cf. *B. exasperata*
Billingsella cf. *B. plicatella* Walcott
- 302t. Meagher limestone: northeast of Logan, Three Forks quadrangle.
Micromitra sculptilis (Meek)
- 302w. Dry Creek shale: Madison Mountain, Montana.
"Acrotreta" tetonensis Walcott

SYSTEMATIC DESCRIPTIONS³

The classification of the Cambrian Brachiopoda, especially of the Gastrocaulia (Atremata and Neotremata), is at present in a state of uncertainty and fluctuation. Rather than to place genera in families whose limits are very inadequately known, or to propose systematic divisions on the basis of the scattered information derived from the present study, the writer has introduced no taxonomic units of higher rank than genera. The arrangement of genera follows that of Schuchert and LeVene (1929) as closely as is feasible.

³ The catalogued specimens referred to in the following descriptions and in the descriptions of plates are preserved at Montana State University (designated "Mont."), the University of Michigan (designated "Mich."), and the United States National Museum (designated "U.S.N.M."). Binary fossil locality designations 6-2 to 53-1 refer to Montana State University localities, binaries M1-4 to M4-4a refer to University of Michigan localities, and United States National Museum localities are designated "U.S.N.M."

Genus MICROMITRA Meek, 1873

A group of more or less closely related species is at present assigned to *Micromitra* Meek, *Paterina* Beecher, and *Iphidella* Walcott. Its members are characterized by a moderately to strongly convex ventral valve, a strongly apsacline to procline ventral pseudointerarea, and, especially, by a minute to large homoeodeltidium. Walcott (1912, p. 336) considered *Paterina* and *Iphidella* to be subgenera of *Micromitra*. He assigned to *Paterina* the species "whose surface is formed of simple concentric striae and lines of growth"; to *Iphidella* those "whose surface is formed by the union of the crenulated striae so as to form a fine network of obliquely arranged lines;" and to *Micromitra* those "with the intermediate type of surface."

The present writer is convinced that some, if not all, of these genera are polyphyletic, and that the type of surface ornamentation cannot be used alone as a criterion for generic separation. As conceived in this paper the species *Micromitra sculptilis* (Meek) contains specimens possessing surface patterns assignable to all three genera as defined by Walcott. Indeed, Walcott himself, in discussing varieties of *Micromitra* (*Iphidella*) *pannula* (White), figured specimens from near Ophir, Utah, which he said (Walcott, 1912, p. 363) "illustrate the entire evolution of the 'pannula' type of surface from the concentric striae to the fine network of oblique, raised lines dividing the surface into minute, diamond-shaped depressions."

So far as the writer is aware, no conclusive proof has yet been offered to support the belief that *Paterina* is characterized by a homoeodeltidium. Walcott (1912, pl. 2, fig. 3c) illustrated a cross section of a specimen of *Paterina labradorica swantonensis* (Walcott), which purports to demonstrate the presence of the homoeodeltidium. However, the section is not cut along the longitudinal axis of the ventral valve, and the "pseudo-deltidium" is merely the strongly curved posterolateral margin of the shell. It should be noted that the shells of *Paterina labradorica* (Billings) and *Paterina labradorica swantonensis* (Walcott) are built up of successive laminae, a condition not observed by the writer in any of the western species assigned at present to *Paterina*.

Walcott (1912, p. 322) classified *Paterina* under the *Atrēmata*. Thomson (1927, p. 116) included it in the *Neotremata* on the basis of holoperipheral growth. Schuchert (in Schuchert and LeVene, 1929) accepted Thomson's new order *Palaeotremata*, included *Paterina* in it, and placed *Micromitra* and *Iphidella* in the *Atrēmata*. The present writer believes that *Micromitra* and *Iphidella* fit best into the *Atrēmata* of the prevailing classification; that in the future a new order will be proposed to contain them, together with new genera based on species now assigned to *Micromitra*, *Paterina*, and *Iphidella*; and that *Paterina* s.s. must be restudied before it can be correctly placed in any classification.

Unfortunately an exhaustive study of *Micromitra* and the related genera (subgenera of Walcott) *Paterina* and *Iphidella* cannot be undertaken at this time. Any comprehensive treatment must involve new collections and many difficult preparations to disclose internal morphology, shell structure, and details of the pseudointerarea in all species now assigned to the three genera. Such a study must be left to the future, and the writer can only contribute here information regarding *Micromitra sculptilis* (Meek), the genotype, and related species occurring with it in Montana.

MICROMITRA SCULPTILIS (Meek)

Plate 28, figures 1-26

Iphidea?? sculptilis MEEK, 1873, U. S. Geol. and Geog. Survey Terr., Sixth Ann. Rept., p. 479.

Kutorgina sculptilis WALCOTT (part), 1884, U. S. Geol. Survey, Mon. 8, p. 20, pl. 1, figs. 7, 7a (not pl. 1, fig. 7b; pl. 9, fig. 7).

Iphidea sculptilis WALCOTT, 1899, U. S. Geol. Survey, Mon. 32, pt. 2, pl. 60, figs. 5, 5a-c.

Micromitra sculptilis WALCOTT (part), 1912, U. S. Geol. Survey, Mon. 51, p. 341, pl. 3, figs. 5, 5a, 5e (not figs. 5b-d).

Iphidea pealei WALCOTT (part), 1897, U. S. Nat. Mus., Proc., vol. 19, p. 712, pl. 59, figs. 3, 3a-b (not fig. 3c).

Micromitra pealei WALCOTT (part), 1912, U. S.

Geol. Survey, Mon. 51, p. 339, pl. 3, figs. 3, 3a-b, 3d-e (not fig. 3c).

Outline transversely subelliptical except for truncated posterior margin with elevated ventral apex projecting slightly beyond it; line of valve junction slightly shorter than greatest width of shell; surface ornamentation basically a rectangular pattern formed by junction of fila and radiating ribs or ridges, often greatly modified in younger portions of shell; shell calcareocorneous, composed of a single homogeneous layer, usually thin.

Ventral valve: Profile obtusely triangular, highest point being at umbo vertically above or slightly anterior to line of valve junction; apex sharply pointed, formed of smooth tip with a pair of low callosities anterolateral to it, strongly incurved over homoeodeltidium; propareas flat, smooth or granular, unstriated; delthyrium high, triangular; delthyrial angle 70°-90°; homoeodeltidium thin, strongly convex, smooth or granular, rising abruptly and continuously from propareas, and more or less completely filling delthyrium. Interior without markings other than reflection of fila and radiating ridges; pair of small projecting knobs of unknown function bordering apex of delthyrium (pl. 28, fig. 13).

Dorsal valve: Profile slightly and more or less evenly convex; apex broadly rounded, slightly incurved over homoeochilidium, carrying a low smooth callosity, which extends anteriorly into four symmetrically arranged lobes, of which the middle two are most prominent; propareas flat, smooth or granular, sometimes crossed parallel to posterior margin by a few lines or low ridges, which are not continuous with fila (pl. 28, figs. 25, 26); notothyrium low, obtusely triangular, more or less completely filled by thin convex homochilidium, which rises smoothly and continuously from propareas. Interior without markings other than reflection of fila and radiating ridges.

	<i>Dimensions (mm.)</i>				
	Length	Width	Height	L/W	H/W
Ventral valves:					
U.S.N.M. 7864a.....	2.2?	2.7	1.1?	0.81	0.41
U.S.N.M. 26430a.....	3.8?	4.8	2.0	0.80	0.42
Mont. T1205a.....	3.2	3.5	1.4?	0.91	0.40
Mich. 20814a.....	1.8	2.1	1.0	0.86	0.48
Dorsal valves:					
Mont. T1203b.....	5.1	7.0?		0.73	
Mont. T1203c.....	5.0	7.5		0.67	

Holotype, U.S.N.M. 7864a; hypotypes, U.S.N.M. 3467a, 26430a; Mont. T1203a-d, T1204a, T1205a-b, T1206a-d, T1207a, T1208a; Mich. 20813a, 20814a, 20818a.

Horizon and locality.—Middle Cambrian. "Pagoda" limestone: 26-3, Lick Creek; 28, loose (?), Rock-Baldy Bear Creek ridge. Pentagon shale: 6-2, Pentagon Mountain; 26-4, Lick Creek. Meagher limestone (*Ehmania* zone): 45-2, M4-3, Nixon Gulch; M3-1, M3-2, Pole Creek. Meagher limestone (*Bathyriscus* zone): 45-3, 45-3a M4-4, M4-4a, Nixon Gulch. Lower Meagher limestone: 47-2T, 47-3 (?), Beaver Creek. Limestone lenses in upper Wolsey shale: 34-5U, South Hill. U.S.N.M. localities: Meagher limestone: 4h, 4p (?), 159, 302,⁴ 302t, near Logan; 155a, near Hillsdale 302b (1), near Crowfoot Ridge; 9h, Beaver Creek; 5k (1), head of Sawmill Creek. Limestone lenses in Wolsey shale: 4x, Belt Park; 5f, head of Sawmill Creek.

Distinguishing characters.—*Micromitra sculptilis* is characterized by a calcareoconeous shell composed of a single layer; a thin, convex homoeodeltidium, which is continuous with the propareas and usually covers most of the delthyrium; and a surface ornamentation that is basically a rectangular pattern resulting from the junction of fila and radiating ribs or ridges, but which may be greatly modified in younger portions of the shell.

Discussion.—An analysis of Walcott's latest (1912, pp. 339, 341) opinions regarding *M. sculptilis* and *M. pealei* reveals several inconsistencies. He does not refer to *M. pealei* in his discussion of *M. sculptilis*, but says that a

study of the specimens of *M. sculptilis* collected from the same horizon, at a point not far distant from the original locality, shows the presence of a false area and a pseudodeltidium (homoeodeltidium) of the same type as that of *M. (Paterina) bella* (Billings).

Thus Walcott implies the presence in *M. sculptilis* of a large homoeodeltidium covering most of the delthyrium. However, in the next paragraph he writes:

The most nearly related species is *M. haydeni* Walcott, which has a similar surface, but the latter has a large pseudodeltidium (homoeodeltidium) on the ventral valve.

⁴ Type locality in italics.

Here he apparently implies a small homoeodeltidium in *M. sculptilis*. The holotype (pl. 28, figs. 5, 11) of *M. sculptilis* has the apex broken, so that all references to a homoeodeltidium must be based on other specimens conspecific with it.

Walcott (1912, p. 339) wrote, in his discussion of *M. pealei*:

This species approaches *M. sculptilis* (Meek) in some examples of the ventral valve. It differs mainly in the narrow pseudodeltidium and the character of the surface markings.

Whether Walcott meant that *M. sculptilis* has no homoeodeltidium, or that the homoeodeltidium is present but different from that in *M. pealei*, is not clear.

Walcott (1912, p. 339) was in error when he stated in his description of *M. pealei* that The striae of growth cross the false area and arch over the delthyrium (homoeodeltidium?).

Both the ventral and dorsal propareas are distinctly separated from the filate and radially ribbed portion of the shell by a distinct ridge formed by the apical flexing and fusion of the fila (pl. 28, figs. 1-6, 15, 20, 25, 26). The propareas are smooth or somewhat granular, and continuous with the convex homoeodeltidium and homoeochilidium. Rarely the propareas bear short, scattered, horizontal ridges, which are not continuous with the fila.

The petaloid callosity (pl. 28, figs. 16, 21, 25) on the dorsal apex of *M. sculptilis* has not before been described. It is low and smooth, and its anterior margin is deeply scalloped into four lobes, the middle two of which are the largest. The first discernible filum closely parallels the scalloped margin of the callosity.

The surface ornamentation of *M. sculptilis* is extremely varied in its expression. The basic pattern, always visible on the apical portion of the shell, consists of rectangles formed by the intersection of the fila and radiating ribs. The fila flex toward the apex at their junction with the radiating ribs, forming a scalloped pattern. On many shells, particularly those from the lower or *Ehmania* zone of the Meagher limestone, the rectangular pattern is clearly defined over the entire surface (pl. 28, figs. 7-9, 11, 20). On many others, however, various modifications of the rectangular pattern occur on the

younger portion of the shell. The radiating ribs may almost disappear anteriorly, leaving only the regular fila (pl. 28, figs. 16, 18). A second variation (pl. 28, figs. 23-24), common on specimens from the *Bathyriscus* zone of the Meagher limestone, is characterized by numerous radiating ridges, rather than ribs, apparently developed from the fusion of segmented fila. In this pattern the segments of fila project laterally from the radiating ridges, alternating in position with the projecting segments of fila composing the adjacent radial ridge. A third variation (pl. 28, figs. 6, 12), most common among valves from the *Ehmania* zone, is characterized by a complex pattern resulting partly from a secondary quincunxial arrangement of ribs, and partly from the change of the rectangles to circular pits. Each of the four types of surface pattern appears to be most characteristic of either the *Ehmania* or *Bathyriscus* zone or their equivalents in northwestern Montana, but all variations are present in each zone, as well as transitional forms between them. Although the writer has had at his disposal large collections of *M. sculptilis* from Montana, he has been unable to find that any of the variations in surface pattern has either stratigraphic or geographic value and has therefore refrained from distinguishing them by name.

Because the present study has revealed wide and inconsistent variations in surface ornamentation among shells otherwise identical with the holotype of *Micromitra sculptilis* (Meek), and because the range of variation includes well within it the types of ornamentation on the holotypes of *M. sculptilis* (pl. 28, figs. 5, 11) and *M. pealei* (pl. 28, figs. 4, 10), and, finally, because the type localities of the two described species are, so far as can be determined, only a few miles apart, the writer feels that *M. sculptilis* and *M. pealei* are merely slightly different members of an extremely variable species, and that present knowledge does not warrant their designation by different names.

MICROMITRA? SUBDITA Bell, n. sp.

Plate 28, figures 27-30

Micromitra pealei WALCOTT (part), 1897, U. S. Nat. Mus., Proc., vol. 19, pl. 59, fig. 3c;—(part), 1912, U. S. Geol. Survey, Mon. 51, pl. 3, fig. 3c.

Outline transversely subelliptical except

for truncated posterior margin, with elevated ventral apex projecting slightly beyond it; line of valve junction slightly shorter than greatest width of shell; concentric surface undulations broad, low, irregularly spaced, curving slightly toward apex at junction with regularly spaced, broad, shallow radiating grooves, and thickened and bent abruptly toward apex on margins of delthyrium and notothyrium; shell thin, dark-brown or black, extremely glossy, calcareoconeous, composed of a single layer.

Ventral valve: Profile probably subtriangular, with apex incurved over posterior margin; delthyrium apparently a broad triangular gape below apex; propareas not observed. Interior unknown.

Dorsal valve: Profile slightly convex, greatest height at umbo of broadly rounded, slightly incurved marginal apex; petaloid callosity faintly visible on apex of holotype, but exact characteristics indeterminable; notothyrium low, widely triangular; notothyrial angle 135°; propareas not observed. Central portion of valve strongly thickened internally; two narrow, high ridges originate slightly forward of an apical depression or pit and diverge anteriorly at an angle of 40°; low, narrow longitudinal ridge midway between them; no muscular impressions observed.

Dimensions (mm.)

	Length	Width	L/W
Ventral valve:			
Mont. T1211b....	2.8?	3.5?	0.80
Dorsal valve:			
Mont. T1211a....	3.4?	5.0?	0.68

Holotype, Mont. T1211a; paratype, Mont. T1211b; figured specimen, Mich. 20815a.

Horizon and Locality.—Middle Cambrian. Pentagon shale: 26-4, Lick Creek. Meagher limestone (*Bathyriscus* zone): 45-3, 45-3a, M4-4, M4-4a, Nixon Gulch. Meagher limestone: U.S.N.M. loc. 155a, near Hillsdale.

Distinguishing characters.—This species is best characterized by its dark brown to black, extremely glossy shell and by its surface ornamentation composed of low concentric ridges, slightly scalloped between intersections with faint radiating grooves. The writer knows of no described species with which it might be confused.

Discussion.—The character of the homoeodetidium, if present, could not be deter-

mined from the available crushed specimens, nor could it be definitely ascertained whether or not propareas were present. Although the assignment of this species to *Micromitra* must be tentative until more completely preserved ventral valves are known, this species appears to be congeneric with *Micromitra sculptilis* in form, shell structure,

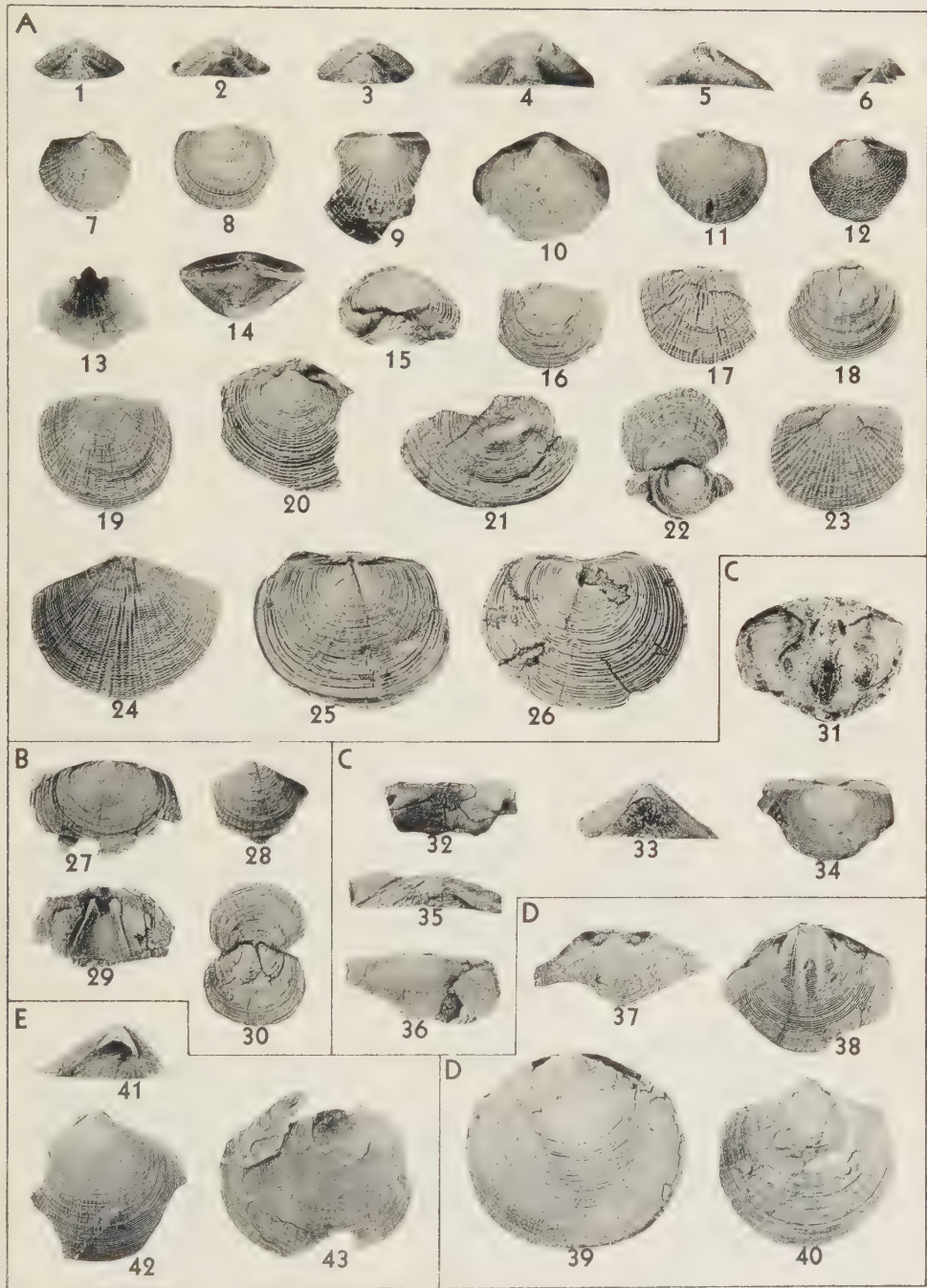
and the presence of a low petaloid callosity at the dorsal apex. No interpretation of the internal structures in the holotype is attempted.

Genus IPHIDELLA Walcott, 1905

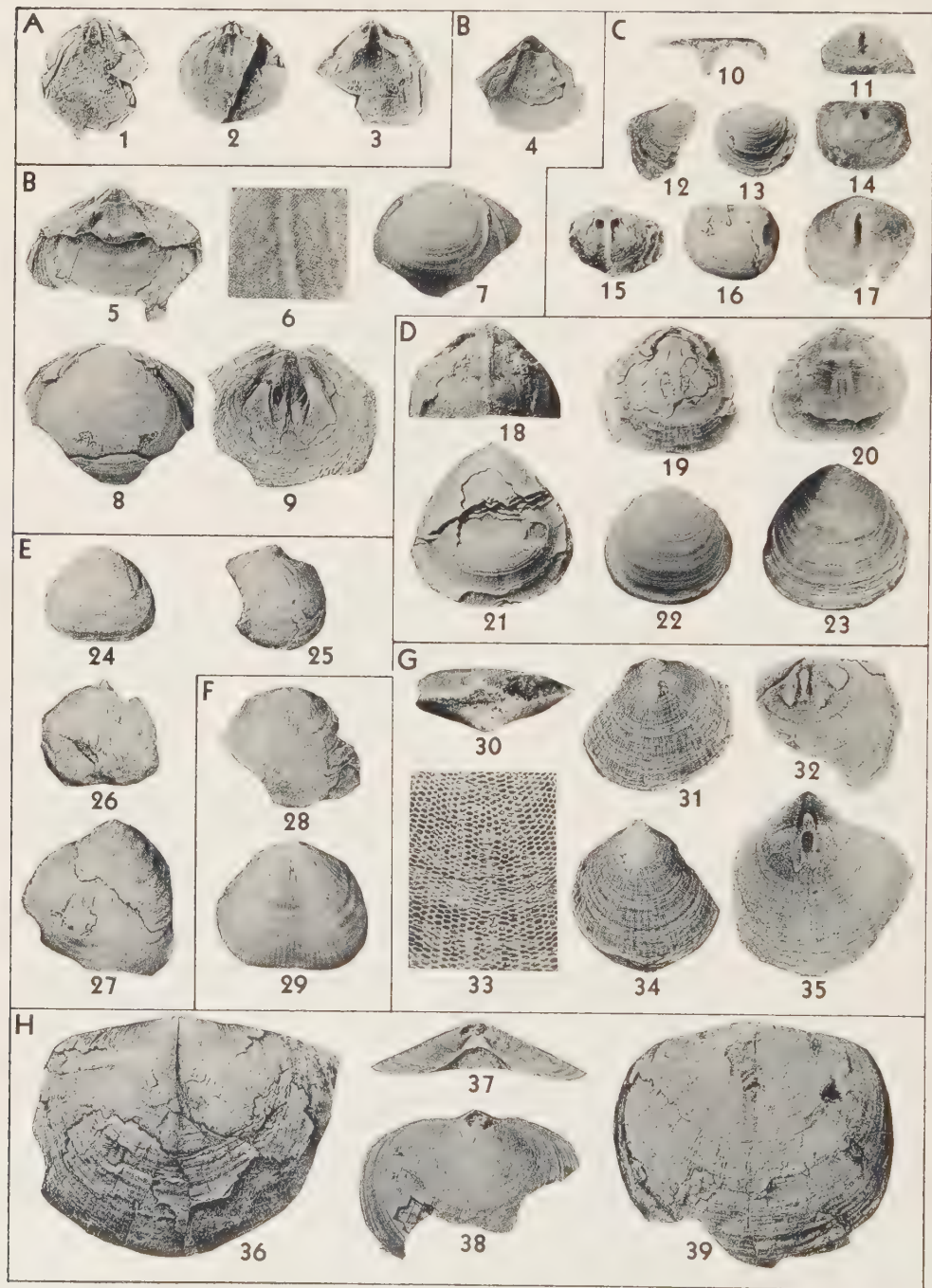
Walcott (1912, p. 336) distinguished the subgenus *Iphidella* from *Micromitra* and *Pa-*

EXPLANATION OF PLATE 28

- FIGS. 1-26—*Micromitra sculptilis* (Meek) 1, 7, Hypotype; posterior and apical views of ventral valve, Mich. 20814a, $\times 6$, loc. M4-3. 2, 8, Hypotype; posterior and apical views of ventral valve, Mont. T1205a, $\times 4$, loc. 47-2T. 3, 9, Hypotype; posterior and apical views of ventral valve, showing structure of apex and distinct propareas, U.S.N.M. 3467a, $\times 4$, loc. 302. 4, 10, Hypotype (Mon. 51, pl. 3, figs. 3, 3a-b, as holotype of *M. pealei*); posterior and apical views of ventral valve, showing propareas and homoeodeltidium, U.S.N.M. 26430a, $\times 4$, loc. 155a. 5, 11, Holotype (Mon. 51, pl. 3, fig. 5); posterior and apical views of incomplete ventral valve, U.S.N.M. 7864a, $\times 6$, loc. 302. 6, 12, Hypotype; posterior and apical views of ventral valve, showing a proparea and part of homoeodeltidium, Mont. T1205b, $\times 4$, loc. 47-2T. 13, Hypotype; interior of incomplete ventral valve, showing convex homoeodeltidium and projecting knob on each side of apex of delthyrium, Mont. T1204a, $\times 6$, loc. 34-5U. 14, Hypotype; posterior view of nearly complete specimen, the surface of which is similar to that of valve in fig. 12, Mich. 20818a, $\times 4$, loc. M3-1. 15, 20, Hypotype; posterior and apical views of ventral valve, showing large homoeodeltidium, distinct propareas, and rectangular surface ornamentation, Mont. T1203a, $\times 4$, loc. 26-3. 16, Hypotype; apical view of incomplete dorsal valve, showing petaloid apex, Mont. T1203d, $\times 4$, loc. 26-3. 17, Hypotype; apical view of dorsal valve, showing a variation in surface ornamentation, Mont. T1207a, $\times 4$, loc. 45-3. 18, Hypotype; apical view of dorsal valve, showing a variation in surface ornamentation, Mont. T1206d, $\times 4$, loc. 6-2. 19, Hypotype; apical view of dorsal valve, Mont. T1206b, $\times 4$, loc. 6-2. 21, Hypotype; apical view of incomplete dorsal valve, showing petaloid apex, Mont. T1208a, $\times 6$, loc. 45-2. 22, Hypotype; apical view of associated incomplete dorsal and ventral valves, Mich. 20813a, $\times 6$, loc. M4-4. 23, Hypotype; apical view of dorsal valve, showing a variation in surface ornamentation, Mont. T1206c, $\times 4$, loc. 6-2. 24, Hypotype; apical view of crushed ventral valve, showing an extreme variation in surface ornamentation, Mont. T1206a, $\times 4$, loc. 6-2. 25, Hypotype; apical view of dorsal valve, showing propareas and homoeochilidium, Mont. T1203b, $\times 4$, loc. 26-3. 26, Hypotype; apical view of incomplete dorsal valve, showing propareas and healed injury, Mont. T1203c, $\times 4$, loc. 26-3. Middle Cambrian: Meagher limestone (*Ehmania* and *Bathyriscus* zones), "Pagoda" limestone, and Pentagon shale. (p. 205)
- 27-30—*Micromitra? subdita* Bell, n. sp. 27, 29, Holotype; exterior and interior views of incomplete dorsal valve, Mont. T1211a, $\times 4$, loc. 26-4. 28, Paratype; apical view of crushed ventral valve, Mont. T1211b, $\times 4$, loc. 26-4. 30, Figured specimen; apical view of associated dorsal and ventral valves, Mich. 20815a, $\times 4$, loc. M4-4. Middle Cambrian: Pentagon shale and Meagher limestone (*Bathyriscus* zone). (p. 207)
- 31-36—*Icodonta typica* Bell, n. gen., n. sp. 31, Syntype; apical view of ventral internal mold, showing impressions of internal callosities and linear ridges bordering apex of delthyrium, Mont. T1210c, $\times 4$, loc. 33-3L. 32, Syntype; interior view of incomplete dorsal valve, showing subconical projection adjoining each posterolateral margin, Mont. T1210d, $\times 6$, loc. 33-3L. 33, 34, Syntype; posterior and apical views of incomplete ventral valve, showing propareas and short homoeodeltidium, Mont. T1210a, $\times 4$, loc. 33-3L. 35, 36, Syntype; posterior and apical views of incomplete dorsal valve, showing propareas and homoeochilidium with flattened crest, Mont. T1210b, $\times 4$, loc. 33-3L. Middle Cambrian: Upper Wolsey shale. (p. 213)
- 37-40—*Icodonta nixonensis* Bell, n. gen., n. sp. 37, Syntype; incomplete dorsal semi-internal mold, Mich. 20817b, $\times 4$, loc. M4-1. 38, Syntype; incomplete ventral semi-internal mold, Mich. 20817a, $\times 4$, loc. M4-1. 39, Syntype; exterior of partly exfoliated dorsal valve, Mich. 20817d, $\times 3$, loc. M4-1. 40, Syntype; exterior of nearly complete but somewhat crushed ventral valve, Mich. 20817c, $\times 3$, loc. M4-1. Middle Cambrian: Wolsey shale. (p. 214)
- 41-43—*Icodonta? cf. I. nixonensis* Bell, n. gen., n. sp. 41, 42, Figured specimen; posterior and apical views of incomplete ventral valve, Mont. T1212a, $\times 4$, loc. 11-2. 43, Figured specimen; external impression of incomplete and crushed valve, showing surface ornamentation like that in fig. 42, Mont. T1213a, $\times 3$, loc. 40-2. Middle Cambrian: Pagoda limestone and Wolsey shale. (p. 214)



Bell, Cambrian Brachiopoda



Bell, Cambrian Brachiopoda

terina solely because its

surface is formed by the union of the crenulated striae so as to form a fine network of raised obliquely arranged lines that divide the surface into minute pits that give the impression of finely woven cloth.

The type locality of the genotype, *Iphidella pannula* (White) is given (Walcott, 1912, p. 364) as "limestone interbedded in the Pioche

shale, just above the quartzite on the east side of the anticline, near Pioche, Lincoln County, Nevada." Deiss (1938, p. 1156, loc. 56-1) collected specimens conspecific with the holotype, so far as can be determined, from 260 feet above the base of the Pioche shale on the west side of the Highland Range Nevada, thus substantiating the Lower Cambrian age of *I. pannula* in its type area.

EXPLANATION OF PLATE 29

- FIGS. 1-3—*Dicellomus politus* (Hall). 1, 2, Hypotypes (Mon. 51, p. 576, t. figs. 49 A-B); interiors of ventral valves in which the surfaces of the propareas have been weathered away, U.S.N.M. 51917a-b, $\times 6$, loc. 79s. 3, Hypotype; interior of ventral valve in which the surfaces of the propareas have been only partly weathered away, U.S.N.M. 51917, $\times 6$, loc. 79s. Upper Cambrian: Eau Claire member of Dresbach formation, Hudson, Wis. (p. 215)
- 4-9—*Dicellomus mosaica* Bell, n. sp. 4, Paratype; interior of incomplete ventral valve, Mont. T1202d, $\times 4$, loc. 44-2. 5, Paratype; interior of incomplete ventral valve, Mont. T1202b, $\times 4$, loc. 44-2. 6, Figured specimen; magnified view of pitted surface pattern, Mich. 20812b, ca. $\times 30$, loc. M1-4. 7, Paratype; exterior of partly exfoliated dorsal valve, Mont. T1202c, $\times 4$, loc. 44-2. 8, Figured specimen; exterior of partly exfoliated dorsal valve, Mich. 20812a, $\times 4$, loc. M1-4. 9, Holotype; interior of dorsal valve, showing muscular scars, Mont. T1202a, $\times 4$, loc. 44-2. Upper Cambrian: Dry Creek shale and Snowy Range formation. (p. 216)
- 10-17—*Ceratreta hebes* Bell, n. gen., n. sp. 10, 12, Syntype; lateral and exterior views of an incomplete dorsal valve, showing hornlike projection of septum, Mont. T1197a, $\times 8$, loc. 46-3. 11, 14, Syntype; posterior and apical views of partly exfoliated ventral valve, Mont. T1197b, $\times 8$, loc. 46-3. 13, Syntype; exterior of nearly complete dorsal valve, Mont. T1197e, $\times 8$, loc. 46-3. 15, Syntype; interior of an incomplete dorsal valve, showing apical shelf and narrow septum from which the hornlike projection has been broken, Mont. T1197d, $\times 10$, loc. 46-3. 16, Syntype; apical view of partly exfoliated ventral valve, showing cross section of internal pedicle tube near posterior margin, Mont. T1197f, $\times 8$, loc. 46-3. 17, Syntype; posterior view of nearly perfect ventral valve, showing blunt apex and deep intertrough incised in apical half of pseudointerarea, Mont. T1197c, $\times 8$, loc. 46-3. Upper Cambrian: Dry Creek shale. (p. 233)
- 18-23—*Dicellomus occidentalis* Bell, n. sp. 18, Syntype; internal mold of incomplete ventral valve, showing propareas and long pedicle furrow merging into spatulate visceral area, Mont. T1200f, $\times 4$, loc. 32-3. 19, Syntype; surface of partly exfoliated dorsal valve, showing large central muscular scars, Mont. T1200d, $\times 4$, loc. 32-3. 20, Syntype; interior of nearly complete dorsal valve, showing small anterior lateral muscular scars in contact with anterior ends of the large elongate central scars, Mont. T1200c, $\times 4$, loc. 32-3. 21, Syntype; exterior of partly exfoliated ventral valve, showing thick laminated shell and radiating bands on inner layers, Mont. T1200e, $\times 4$, loc. 32-3. 22, 23, Syntypes; exteriors of dorsal and ventral valves, Mont. T1200a-b, $\times 4$, loc. 32-3. Upper Cambrian: Pilgrim limestone. (p. 218)
- 24-27—*Schuchertina cambria* Walcott. 24, 27, Paratypes (Mon. 51, pl. 51, figs. 6g, 6a); exteriors of two ventral valves, U.S.N.M. 51411f, 51411b, $\times 1$, loc. 5k. 25, Holotype (Mon. 51, pl. 51, figs. 6b-c, as ventral valve); internal mold of a dorsal valve, U.S.N.M. 51411c, $\times 1$, loc. 5k. 26, Paratype (Mon. 51, pl. 51, fig. 6j, as a dorsal valve); internal mold of ventral valve, U.S.N.M. 51411h, $\times 1$, loc. 5k. Middle Cambrian: Meagher limestone. (p. 215)
- 28, 29—*Schuchertina* cf. *S. cambria* Walcott. 28, Figured specimen; internal mold of incomplete dorsal valve, Mont. T1193b, $\times 1$, loc. 42-2. 29, Figured specimen; internal mold of incomplete dorsal valve, Mont. T1193a, $\times 2$, loc. 42-2. Middle Cambrian: Meagher limestone. (p. 215)
- 30-35—*Iphidella hexagona* Bell, n. sp. 30, 31, 34, Syntype; posterior, dorsal, and ventral views of a nearly complete specimen, Mich. 20816a, $\times 4$, loc. M3-1. 33, Syntype; enlarged view of surface ornamentation of same specimen, Mich. 20816a, $\times 15$, loc. M3-1. 32, Syntype; interior of incomplete dorsal valve, U.S.N.M. 97078a, $\times 4$, loc. 20k. 35, Syntype; interior of incomplete ventral valve, Mich. 20816b, $\times 4$, loc. M3-1. Middle Cambrian: lower Meagher limestone. (p. 210)
- 36-39—*Iphidella nyssa* Walcott. 36, Paratype (Mon. 51, pl. 3, fig. 9a); exterior of crushed and partly exfoliated dorsal valve, U.S.N.M. 51441b, $\times 3$, loc. 4q. 37, 38, Hypotype; posterior and apical views of incomplete ventral valve, Mont. T1209a, $\times 3$, loc. 23-1. 39, Holotype (Mon. 51, pl. 3, fig. 9, as a ventral valve); exterior of crushed and partly exfoliated dorsal valve, U.S.N.M. 51441a, $\times 3$, loc. 4q. Middle Cambrian: Gordon shale. (p. 212)

The species has been reported from British Columbia, Alberta, Montana, Idaho, Utah, Nevada, Arizona, New York, Tennessee, and Georgia; and from rocks ranging in age from Lower to Upper Cambrian. Obviously, as now conceived, *I. pannula* possesses neither stratigraphic nor geographic significance, and must be restudied. This problem cannot be undertaken in the present study, but it is thought that certain observations on the genotype can with profit be included here.

The holotype of *Iphidella pannula* (White) is a badly weathered shell fragment, which has a faint surface pattern composed of imperfect diamond-shaped pits formed by the oblique intersection of narrow ribs. The only topotype in the United States National Museum which is not defaced to some extent shows a distinct quincunxial pattern in which the diamond-shaped spaces between the ridges are somewhat filled and rounded. This pattern is diagrammatically shown by Walcott (1912, pl. 4, fig. 1o). None of the specimens from the type locality shows any details of the interarea, but a ventral valve from U.S.N.M. loc. 30 (Walcott, 1912, pl. 4, figs. 1d, 1e), also in Lincoln County, has a short homoeodeltidium and ill-defined propareas. The ornamentation of this shell apparently consists of imperfect hexagonal pitting, with a trace of quincunxial ridging near the margin. A single nearly complete ventral valve from loc. 56-1 (Deiss, 1938, p. 1156) shows a pattern identical with that on the topotypes, but no evidence of propareas or a homoeodeltidium. The topotypes and specimens apparently conspecific with them range in width from 2-3 mm.

It appears from this brief survey of specimens from the type and nearby localities in the Pioche shale, that *Iphidella pannula* is characterized by a calcareoconeous shell composed of a single layer, transversely subelliptical outline, obliquely subconical ventral valve with obtusely pointed overhanging apex, nearly flat dorsal valve, surface pattern of diamond-shaped pits produced by the oblique intersection of narrow ridges, and perhaps distinct propareas and a short homoeodeltidium.

Until the species at present assigned to *Iphidella* can be restudied, the genus may be tentatively considered as having a *Micro-*

mitra-like form, with a pitted surface ornamentation.

IPHIDELLA HEXAGONA Bell, n. sp.

Plate 29, figures 30-35

Iphidella pannula (White). WALCOTT (part), 1912, U. S. Geol. Survey, Mon. 51, pl. 4, figs. 1b, 1f, 1t (not figs. 1, 1a, 1c-e, 1g-s).

Outline subsemicircular except for pointed ventral beak (apical angle 110° - 120°) projecting well posterior to line of valve junction, which is slightly less than greatest width of shell; surface covered by radiating rows of adjacent hexagonal pits, the hexagons of each row interlocking alternately with hexagons of bordering rows; each row retains its identity from apex nearly to margin, with rare intercalation of new rows; pits minute and indistinct near apex becoming progressively larger and more transverse toward margin, and finally replaced by irregular concentric ridges in some gerontic shells; shell thick, calcareoconeous, composed of a single layer.

Ventral valve: Convexity slight near anterior margin, increasing strongly along median axis to highest point slightly posterior to line of valve junction; apex slightly incurved over delthyrium, smooth, pointed, with pair of low callosities anterolateral to it, as is *Micromitra sculptilis* (Meek); propareas narrow, smooth or granular, unstriated; delthyrium high, triangular; delthyrial angle about 135° ; homoeodeltidium probably minute, if present, but not observed. Delthyrial cavity with a pair of narrow subparallel furrows, which diverge anteriorly around a high elongate callosity situated about at the line of valve junction; callosity splits anteriorly into a pair of low, broad elevations which curve around an elongate elliptical depression and approach each other again toward middle of valve (pl. 29, fig. 35).

Dorsal valve: Profile moderately convex, highest point being at umbo vertically above line of valve junction; apex slightly incurved over notothyrium, rounded, bearing a smooth petaloid callosity, as in *Micromitra sculptilis*; propareas narrow, smooth or granular, unstriated; notothyrium low, widely triangular; notothyrial angle about 135° ; homoeochildium not observed in the types. Notothyrial cavity with short median cal-

losity, from posterior end of which a pair of broad flabellate elevations diverge anteriorly (pl. 29, fig. 32).

Syntypes, Mich. 20816a-b, U.S.N.M. 97078a.

Horizon and locality.—Middle Cambrian. Meagher limestone (*Ehmania* zone): M3-1 U.S.N.M. localities 20k and 149a (?), Pole Creek. Pagoda limestone: 11-2, Dearborn

western Montana, suggesting that perhaps some form of articulation had been developed in this species, but no structures have been observed that might have functioned in such a manner.

Walcott (1912, pp. 335, 362, pl. 4, figs. 1b, 1f) illustrated and discussed a dorsal valve from U.S.N.M. loc. 149a, Pole Creek, several miles east of the type locality of *I. hex-*

	Dimensions (mm.)				
	Length	Width	Height	L/W	H/W
Ventral valves:					
Mich. 20816a.....	5.3?	5.5?	1.0?	0.96	0.18
Mich. 20816b.....	6.5?	7.5?		0.87	
Dorsal valves:					
Mich. 20816a.....	4.6?	5.5?		0.84	
U.S.N.M. 97078a.....	5.0?	6.5?		0.77	

Canyon; 30-2, Cliff Mt.; 51-1, Prairie Reef Mt.

Distinguishing characters.—*Iphidella hexagona* is characterized by its ventral valve being extended posteriorly into an obtusely acuminate beak, the apex of which lies well beyond the line of valve junction; a widely triangular delthyrium, oriented in a plane 35°–40° apsacline, with perhaps a minute homoeodeltidium at its apex; a surface ornamentation composed of radiating rows of interlocking hexagonal pits; and internal structures so far unknown in any other brachiopod.

Discussion.—This species is assigned at present to *Iphidella*, but with the expressed belief that when the internal characters of *I. pannula* are made known the two species will be found to differ generically. The writer hesitates to establish a monotypic genus upon a species whose morphology is so incompletely understood, and which belongs to such a poorly known group of species as those now assigned to *Micromitra*, *Paterina*, and *Iphidella*.

The pattern of internal callosities in *Iphidella hexagona*, which presumably represent points of muscular attachment, remotely resembles that in the most primitive calcareous "articulates." This is particularly true in the ventral valve, where the median callosity may have borne the "adductors" and the pair of callosities anterior to it, the "diductors." Numerous specimens of *I. hexagona* in which the two valves are still "articulated" are known from the Pagoda formation of north-

agona. He described a "narrow median groove extending from the apex to the posterior margin of the pseudodeltidium" (homoeochilidium). This groove is unquestionably the result of crushing. An associated undeformed dorsal valve has a large homoeochilidium with a low median callosity at its margin (compare pl. 28, fig. 35). Walcott also stated that "striae of growth extend across the false areas and pseudodeltidia in both valves." On the contrary, the propareas in *I. hexagona* are smooth or granular, unstriated, and sharply separated from the ornamented portion of the valve. They are, in fact, identical with the propareas in *Micromitra sculptilis*.

The shells from U.S.N.M. loc. 149a are somewhat doubtfully referred to *Iphidella hexagona*. Their large size and the presence of a large homoeochilidium in the dorsal valve suggest *I. nyssa* Walcott. However, the internal radial banding present in the types of *I. nyssa* is not present in the specimens from loc. 149a, and the surface pits on the latter species are distinctly hexagonal, whereas the pits on *I. nyssa* are quadrangular or subcircular.

Iphidella hexagona closely resembles *Iphidella pannula maladensis* (Walcott), from which it differs in the outline of the ventral valve, and in surface ornamentation. From *Iphidella eguchii* Resser and Endo (1937, p. 109, pl. 21, figs. 14, 15), which apparently has an identical surface pattern, it seems to differ in the form of the ventral valve.

IPHIDELLA NYSSA Walcott

Plate 29, figures 36-39

Micromitra (Iphidella) nyssa WALCOTT, 1908, Smithsonian Misc. Coll., vol. 53, no. 3, p. 57, pl. 7, fig. 5; WALCOTT, 1912, U. S. Geol. Survey, Mon. 51, p. 360, pl. 3, figs. 9, 9a.

Shell large for the genus; outline somewhat transversely subelliptical except for slight truncation of posterior margin; line of valve junction considerably shorter than greatest width of shell; surface covered by adjacent subquadrangular pits, roughly arranged in radiating rows, and apparently produced by oblique intersection of raised ridges; shell calcareoconeous, composed of a single layer.

Ventral valve: Profile subtriangular, with highest point above line of valve junction; apex broken on hypotype, but probably slightly incurved; delthyrium moderately high, widely triangular; delthyrial angle about 100°; apical third of delthyrium closed by homoeodeltidium; propareas wide, smooth, continuous with homoeodeltidium; homoeodeltidium thick, strongly convex, with lower margin arched and continuous with sides of delthyrium. Interior unknown.

Dorsal valve: Profile probably slightly convex, with highest point above line of valve junction; character of apex unknown; propareas smooth and unstriated; homoeochilidium present in holotype, short, thick, nearly flush with propareas. Interior unknown except for adjacent narrow radiating bands visible on internal mold of holotype.

	Dimensions (mm.)				
	Length	Width	Height	L/W	H/W
Ventral valve:					
Mont. T1209a.....	8.0?	10.3?	2.3?	0.78	0.21
Dorsal valves:					
U.S.N.M. 51441a.....	11.5?	12.8?		0.90	
U.S.N.M. 51441b.....	11.7?	15.0?		0.78	

Holotype, U.S.N.M. 51441a; paratype, U.S.N.M. 51441b; hypotype, Mont. T1209a.

Horizon and locality.—Middle Cambrian. Upper Gordon shale: 9-2 (?), Pagoda Mt.; 23-1, head of Ahorn Creek; 53-1, Kid Mt.; U.S.N.M. localities 4q, ridge between Gordon and Youngs Creeks; 4v, Gordon Creek.

Distinguishing characters.—*Iphidella nyssa* is distinguished from all species at present assigned to the genus by its large size, form of the ventral valve, excessively wide delthyrium, and subrectangular surface pits.

Discussion.—The type lot of *I. nyssa* in the U. S. National Museum comprises only dorsal valves, the holotype being a dorsal instead of a ventral valve as described by Walcott (1912, pl. 3, fig. 9). It possesses a broad short homoeochilidium, crushed inward and broken. The ventral valve from loc. 23-1 (pl. 29, figs. 37-38) is designated a hypotype of this species because of its large size, transversely subelliptical outline, similar surface pattern, and occurrence near the type locality. Quite probably when the internal characters of *I. pannula* and *I. nyssa* are made known, the two species will be found to differ generically.

Genus ICODONTA Bell, n. gen.

(Gr. *ekós*, perhaps; *δόντος*, teeth)

Outline subcircular to somewhat transversely subelliptical, posterior margin slightly truncated; line of valve junction less than greatest width of shell; surface coarsely and evenly filate, with irregular and discontinuous radiating crenulations in apical portion of the genotype; shell substance calcareoconeous, homogeneous, thick.

Ventral valve: Profile triangular, greatest height at pointed apex, which is at or slightly anterior to line of valve junction; propareas distinct, smooth, sometimes with a few ridges or grooves which are not continuous with fila; delthyrium high, widely triangular; delthyrial angle about 80°; homoeodeltidium thick, sharply separated from propareas, ridged or striated parallel to arched

lower margin, and covering less than a third of delthyrium. Interior with broad, elongate median callosity near middle of anterior slope, bordered by pair of broad, slightly elongate, but less high callosities; pair of narrow elongate ridges border apex of delthyrium (pl. 28, fig. 31).

Dorsal valve: Profile slightly convex, with highest point at broadly rounded apex above line of valve junction; propareas distinct, smooth; notothyrium low, widely triangular, notothyrial angle about 110° in genotype;

homoeochilidium present in genotype, thick, distinctly separated from propareas, gently arched at lower margin, bearing median flattening or ridge, and covering about a third of notothyrium. Interior with a large callosity (subconical in genotype, with cuplike depression lateral to it) on each side of notothyrium near posterior margin (pl. 28, fig. 32).

Genotype, *Icodonta typica* Bell, n. sp.

Discussion.—The species referred to *Icodonta* in this paper would normally be assigned to *Paterina* upon the basis of their *Micromitra*-like form and their strong and regular fila. A mention of the present uncertainty regarding the morphology and relationships of *Paterina* has been made under the discussion of *Micromitra*. In light of that uncertainty, and because the species here assigned to *Icodonta* appear to differ from the genotype of *Micromitra* in several fundamental respects, the genus *Icodonta* is proposed.

Icodonta is distinguished from *Micromitra* by its much thicker shell, particularly in the genotype, its short and thick homoeodeltidium and homoeochilidium, which appear to be individually secreted plates rather than convex continuations of the propareas as in *Micromitra sculptilis*, and by internal structures, which have not been observed in the genotype of *Micromitra*.

The internal morphology of *Icodonta*, best known in *I. typica*, is of particular interest. The strong median and bounding callosities in the ventral valve (pl. 28, figs. 31, 38) presumably are for muscular implantation and remotely resemble, as in the case of *Iphidella hexagona* (pl. 29, fig. 35) described in this paper, the primitive orthid muscular pattern. A similarity between *Icodonta typica* and *Micromitra sculptilis* is seen in the pair of linear ridges bordering the apex of the delthyrium (pl. 28, figs. 13, 31). No function has been postulated for these projections.

The most interesting internal structures observed in *Icodonta* appear in the dorsal valve. A prepared fragment of a dorsal valve of *I. typica* (pl. 28, fig. 32) and a compressed valve of *I. nixonensis* (pl. 28, fig. 37) reveal strong thickenings of the shell on both sides of the notothyrium near the posterior margin of the valve. In *I. typica*, where they can best be observed, the thickenings are in the

form of a pair of subconical projections, with a cuplike depression adjacent and lateral to each. These projections appear to be analogous to the brachiophores of the primitive orthids, and the cuplike depressions are tentatively construed to be sockets for the reception of teeth in the ventral valve. Unfortunately, the presence or absence of teeth could not be positively ascertained with the specimens available.

The present study of *Icodonta* and *Iphidella hexagona* has revealed types of internal morphology that suggest closer affinities between the so-called articulates and inarticulates than has heretofore been suspected. However, until the internal morphology of other species in the *Micromitra-Paterina-Iphidella* group is made known, little can be gained by speculation regarding the apparent affinities.

ICODONTA TYPICA Bell, n. sp.

Plate 28, figures 31–36

Outline subsemicircular; line of valve junction slightly less than greatest width of shell; surface fila distinct, rounded, smoothly concentric, gradually increasing in size from apex to margin, rarely bifurcating and coalescing, and regularly spaced at intervals equal to width of each filum; several low, narrow, irregular, discontinuous crenulations or ridges, on which fila may or may not be obliterated, radiate from apex of each valve and extend toward middle of anterior slope; shell calcareoconeous, homogeneous, thick.

Ventral valve: Profile trigonal, highest point at erect, obtusely pointed apex, which is vertically above or slightly anterior to line of valve junction; propareas flat, smooth except for irregularly spaced vertical grooves, which are separated from filate portion of valve by sharp ridges; delthyrium high, triangular; delthyrial angle about 80°; homoeodeltidium convex, short, thick, sharply separated from propareas, ridged parallel to lower arched margin, and occupying nearly a third of the delthyrium. Interior with high, longitudinally elliptical callosity situated about halfway from apex to anterior margin; low subcircular callosity about halfway from apex to margin on each anterolateral slope; pair of short, narrow ridges border apex of delthyrium.

Dorsal valve: Profile slightly convex, highest point at rounded apex vertically above line of valve junction; propareas flat, smooth; notothyrium low, widely triangular; notothyrial angle about 110° ; homoeochilidium convex, thick, ridged parallel to gently arched margin, covering about a third of notothyrium, sharply separated from propareas, flattened on top to form triangular surface, whose sides diverge from apex. Interior with a subconical projection on each side of notothyrium near posterior margin of valve, each projection having a cuplike depression adjacent and lateral to it.

<i>Dimensions (mm.)</i>			
	Width	Height	H/W
Ventral valves:			
Mont. T1210a....	5.0?	2.1	0.42
Mont. T1210c....	6.0?		
Dorsal valve:			
Mont. T1210b....	5.5?	1.2	0.22

Syntypes, Mont. T1210a-d.

Horizon and locality.—Middle Cambrian. Limestone lenses in upper part of Wolsey shale: 33-3L, 33-3U, *Keegan Butte*.

Distinguishing characters.—This species is characterized by shell outline and profile, radiating crenulations on umbo, flattened surface on homoeochilidium, and internally by a pair of subconical projections on the posterolateral margins of the dorsal valve.

Discussion.—The internal characters of *I. typica* have been discussed in connection with the genus.

The ventral valve of *Paterina stuarti* Walcott resembles that of *I. typica* internally but differs distinctly from it in profile and surface characters.

ICODONTA NIXONENSIS Bell, n. sp.

Plate 28, figures 37-40

All specimens from the type locality have been obtained from a soft shale and occur in a flattened condition.

Outline subcircular except for obtusely acuminate ventral beak; line of valve junction less than greatest width of shell; surface very evenly and coarsely filate; shell calcareous, probably quite thick in original state.

Ventral valve: Propareas apparently present, smooth; character of delthyrium and homoeodeltidium, if present, unknown on specimens from type locality. Interior with

an elongate callosity near middle of anterior slope, bordered by a pair of less distinct, elongate callosities; apparently a pair of narrow, high ridges border apex of delthyrium (compare with *I. typica*).

Dorsal valve: Interior with posterolateral margins strongly thickened.

<i>Dimensions (mm.)</i>			
	Length	Width	L/W
Ventral valve:			
Mich. 20817c.....	7.8	8.2	0.95
Dorsal valve:			
Mich. 20817d.....	9.2	10.0	0.92

Syntypes, Mich. 20817a-d.

Horizon and locality.—Middle Cambrian. Upper Wolsey shale: M4-1, 45-1, *Nixon Gulch*; 40-2, Big Snowy Mts. Pagoda limestone: 11-2 (?), Dearborn Canyon.

Distinguishing characters.—This species is distinguished from *I. typica* by its somewhat more regular and coarse fila and its lack of radial crenulations near the apex.

Discussion.—Two semi-internal molds (pl. 28, figs. 37-38) from the type locality show an internal morphology which approximates that in *I. typica*. The exact bilateral arrangement of both the dorsal and ventral structures seems to rule out any possibility of their being accidental, but their manner of occurrence is inexplicable. The specimens have every appearance of being internal impressions of valves that had strong internal thickenings, but, strangely enough, a thin layer of shell substance, carrying the surface fila, covers much of each "internal mold." Possibly solution has removed all but a thin surface layer of the shell, which has been pressed down upon the internal mold.

A single ventral valve (pl. 28, figs. 41-42) from the Pagoda limestone in Dearborn Canyon is assigned tentatively to this species because it has regular and coarse fila and lacks radial crenulations near the apex. Except for these surface characters, the valve is essentially identical in form with the ventral valve of *Icodonta typica*. Its ornamentation differs slightly from that of *I. nixonensis* in that the fila are broken or subduced in such a manner that numerous narrow bands, uncrossed by fila, radiate toward the shell margin. An external impression (pl. 28, fig. 43) of a valve from the Wolsey shale in the Big Snowy Mountains has the same ornamentation as the ventral valve

from the Pagoda limestone. These two specimens may belong to a new species of *Icodonta* or to some other genus, but because they are the only specimens from their respective localities, they are assigned for the present to *I. nixonensis*, with which they appear to have the closest affinities.

Genus SCHUCHERTINA Walcott, 1905

SCHUCHERTINA CAMBRIA Walcott

Plate 29, figures 24–27

Schuchertina cambria WALCOTT, 1905, U. S. Nat. Mus., Proc., vol. 28, p. 323;—1912, U. S. Geol. Survey, Mon. 51, p. 585, pl. 51, figs. 6, 6a–m.

Four very poorly preserved specimens (pl. 29, figs. 28–29) from Checkerboard Creek are tentatively assigned to this species. They add no information regarding the unique internal markings of *Schuchertina cambria*.

A study of the type specimens of *S. cambria* suggested to the writer that Walcott was in error in certain of his interpretations of the species. The shell material (?) is dark-grey structureless calcite, without either exo- or endo-punctae. It effervesces violently in acid and leaves no residue. The ventral valve is subtrigonal in outline and the dorsal valve somewhat transversely ovate. In the writer's opinion Walcott misinterpreted the dorsal and ventral interiors, his (1912, pl. 51) figures 6, 6a, 6g, 6j–k being ventral valves, and the figures 6b–c, 6d–e, 6h–i, 6l–m being dorsal valves. None of the internal markings appears to be a muscular scar, and Walcott's comparison of the musculature to that in the Billingsellidae seems to be without foundation. However, no alternative interpretation for the markings is proposed, except to suggest that they are entirely pallial in origin.

The original locality from which *Schuchertina cambria* was collected has never been rediscovered, and consequently its exact stratigraphic position is unknown. The specimens in the United States National Museum collection labeled loc. 5k occur in two kinds of matrix. One, a light-colored, coarsely crystalline limestone, carries specimens of *Dicellomus occidentalis* Bell, n. sp.; and the other, a dark-grey, finely crystalline limestone, contains *Micromitra sculptilis* (Meek) *Nisusia* cf. *N. deissi* Bell, n. sp., and *Schuchertina cambria*. Trilobites in the latter ma-

trix belong to new genera according to Resser.⁵ Apparently the collection from loc. 5k was made from both Middle and Upper Cambrian rocks. Because the brachiopods associated in the same matrix with *S. cambria* at loc. 5k are species known elsewhere from the Meagher limestone, and in light of the discovery of *S. cf. S. cambria* in the Meagher limestone on Checkerboard Creek, the horizon of *S. cambria* seems definitely assignable to the Meagher.

Dimensions (mm.)

	Length	Width	L/W
Ventral valves:			
U.S.N.M. 51411f..	13.2	16.0	0.83
U.S.N.M. 51411h..	15.0	16.0	0.94
Dorsal valve:			
U.S.N.M. 51411c..	14.0	17.0?	0.82

Holotype, U.S.N.M. 51411c; paratypes, U.S.N.M. 51411a–b, d–j; figured specimens, Mont. T1193a–b.

Horizon and locality.—Middle Cambrian. Meagher limestone: 42-2 (?), Checkerboard Creek; U.S.N.M. loc. 5k (1), head of Sawmill Creek.

Genus DICELOMUS Hall, 1873

Plate 29, figures 1–3

In his discussion of the genotype, *Dicellomus politus* (Hall), Walcott (1912, p. 576, text figs. 49A–B) illustrated a structure which he described as

... a concave plate in the pedicle furrow, the edges of which rise above the plane of the cardinal area; this plate is evidently the beginning in *Dicellomus* of the pedicle tube. . . .

The specimens from which Walcott's drawings were made are illustrated on plate 29, figures 1, 2. These interiors are associated with many others like them on the surface of a fine-grained yellow sandstone, and have been exposed by weathering. The vascular nature of the "cardinal areas" bordering the so-called "pedicle tube" appeared to the writer to be abnormal, a belief that was substantiated when the specimen illustrated on plate 29, figure 3, was found, associated with the valves noted by Walcott. The "pedicle tube" is a structure produced by the weathering away of the surface layer of the propeas, leaving the margins of the pedicle furrow standing free. Thus, the ventral pseudointerarea is of normal atremate char-

⁵ Personal communication.

acter, and except that the flat propareas are steeply inclined toward each other, the pseudointerarea of *Dicellomus politus* resembles closely that of species of "*Obolus*" and "*Lin-gulella*" associated with it.

Walcott (1912, p. 572, pl. 52, figs. 1i-j) illustrated two dorsal valves in which the posterolateral margins are

hollowed out so as to form a shallow groove on each side, apparently for the reception of the short tooth of the ventral valve.

These two valves now have the posterior margin broken away. The writer has never seen a posterior margin such as that illustrated and described by Walcott in any other specimen of *Dicellomus*. Inasmuch as the structure designated a "tooth" by Wal-

cott is in reality the projecting corner of the mistakenly identified "pedicle tube," the interpretation of *Dicellomus* as an "articulate" brachiopod should be regarded with suspicion until further substantiated.

DICELLOMUS MOSAICA Bell, n. sp.

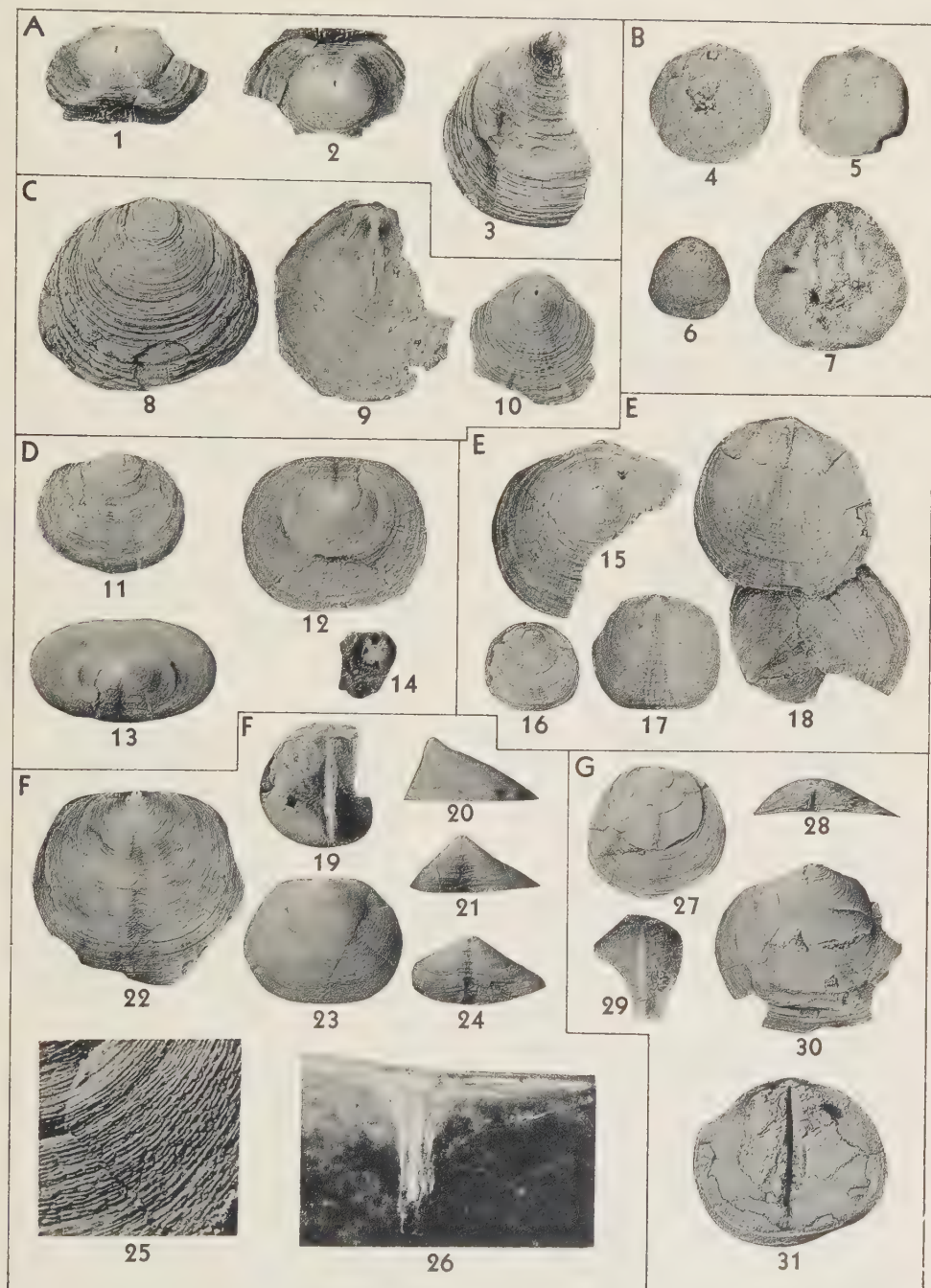
Plate 29, figures 4-9

Dicellomus nanus (Meek and Hayden). WALCOTT (part), 1912, U. S. Geol. Survey, Mon. 51, pl. 53, figs. 3, 3c-d.

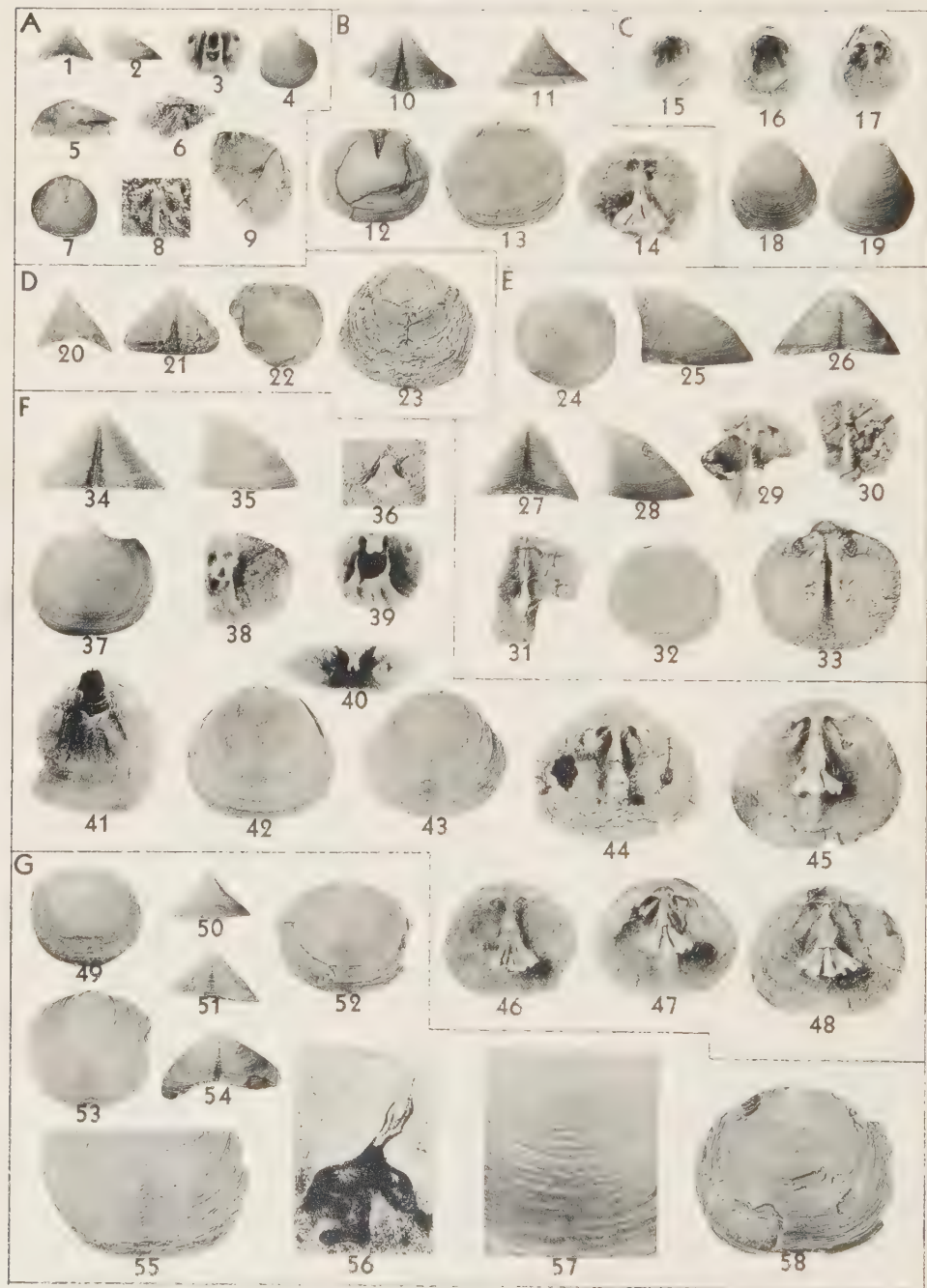
Outline transversely subelliptical except for obtusely acuminate ventral beak; apical angle about 125°; profile moderately and subequally biconvex, the greatest height near middle of shell; surface subdued and sparsely filate, closely and minutely pitted; shell calcareoconeous, composed of several

EXPLANATION OF PLATE 30

- FIGS. 1-3—*Acrothele colleni* Walcott. 1, 2, Paratype (Mon. 51, pl. 63, fig. 6a); posterior and apical views of incomplete ventral valve, U.S.N.M. 51973b, $\times 4$, loc. 4q. 3, Hypotype; exterior of incomplete dorsal valve showing preumbonal depression and tubercles at apex, U.S.N.M. 51973d, $\times 4$, loc. 4q. Middle Cambrian: Gordon shale. (p. 219)
- 4-7—*Acrothele clarki* (Walcott). 4, 7, Paratypes (Mon. 51, pl. 82, figs. 7a-b); internal molds of ventral valves, U.S.N.M. 52214b-c, $\times 4$, loc. 9k. 5, Paratype (Mon. 51, pl. 82, fig. 7c); internal mold of incomplete dorsal valve, U.S.N.M. 52214d, $\times 4$, loc. 9k. 6, Holotype (Mon. 51, pl. 82, fig. 7, as holotype of *Dearbornia clarki*); internal mold of ventral valve, showing fragment of corneous shell substance enclosing cast of pedicle tube, U.S.N.M. 52214a, $\times 4$, loc. 9k. Middle Cambrian: possibly Damnation limestone. (p. 219)
- 8-10—*Acrothele pentagonensis* Bell, n. sp. 8, 9, Syntypes; exterior and interior of dorsal valves, Mont. T1196b-c, $\times 3$, loc. 26-4. 10, Syntype; apical view of incomplete ventral valve, Mont. T1196a, $\times 3$, loc. 26-4. Middle Cambrian: Pentagon shale. (p. 221)
- 11-14—*Pegmatreta perplexa* Bell, n. gen., n. sp. 11, Syntype; exterior of crushed dorsal valve, Mich. 20810b, $\times 10$, loc. M4-4. 12, 13, Syntype; apical and posterior views of ventral valve, Mich. 20810a, $\times 10$, loc. M4-4. 14, Syntype; interior of apex of ventral valve, showing subconical callosity with deep pit excavated into its posterior slope, Mich. 20810c, $\times 10$, loc. M4-4. Middle Cambrian: Meagher limestone (*Bathyriscus* zone). (p. 232)
- 15-18—*Acrothele panderi* Walcott. 15, Hypotype; apical view of incomplete mature ventral valve, U.S.N.M. 52002c, $\times 3$, loc. 5j. 16, Holotype (Mon. 51, pl. 59, fig. 5); apical view of immature ventral valve, U.S.N.M. 52003a, $\times 4$, loc. 4v. 17, Paratype (Mon. 51, pl. 59, fig. 5a); exterior of strongly sulcate dorsal valve, U.S.N.M. 52003b, $\times 4$, loc. 4v. 18, Hypotypes; exterior of two slightly sulcate dorsal valves, one of which is partly exfoliated, U.S.N.M. 52002d, $\times 3$, loc. 5j. Middle Cambrian: Gordon shale. (p. 220)
- 19-26—*Homotreta interrupta* Bell, n. gen., n. sp. 19, Syntype; interior of incomplete dorsal valve, showing pseudointerarea and bladeli-like septum (see text, fig. 2, for profile), Mont. T1194f, $\times 6$, loc. 26-3. 20, 21, 23, Syntype; lateral, posterior, and apical views of ventral valve with slightly broken apex, Mont. T1194b, $\times 6$, loc. 26-3. 22, Syntype; exterior of dorsal valve, showing criss-cross pattern of fila in shallow sulcus, Mont. T1194c, $\times 10$, loc. 26-2. 24, Syntype; posterior view of ventral valve, showing pedicle foramen and deep intertrough, Mont. T1194a, $\times 10$, loc. 26-3. 25, Syntype; enlarged view of surface of incomplete ventral valve, showing segmented fila, Mont. T1194d, ca. $\times 20$, loc. 26-2. 26, Syntype; greatly magnified view of thin section of dorsal septum at its highest point (see text fig. 1, for serial sections), Mont. T1194g, ca. $\times 54$, loc. 26-3. Middle Cambrian: "Pagoda" limestone. (p. 230)
- 27-31—*Pegmatreta rotunda* Bell, n. gen., n. sp. 27, Syntype; exterior of dorsal valve, Mont. T1195b, $\times 6$, loc. 26-3. 28, 30, Syntype; posterior and apical views of crushed ventral valve, showing distinct intertrough, Mont. T1195a, $\times 6$, loc. 26-3. 29, Syntype; interior of incomplete dorsal valve, showing part of apical pit and low median septum, Mont. T1195d, $\times 10$, loc. 26-3. 31, Syntype; partial internal mold of dorsal valve, showing impressions of apical pit, obsolete propareas, and median septum, Mont. T1195c, $\times 6$, loc. 26-3. Middle Cambrian: "Pagoda" limestone. (p. 232)



Bell, Cambrian Brachiopoda



Bell, Cambrian Brachiopoda

layers, of which the inner ones are radially banded; pitting of inner layers less distinct than in *D. politus* and *D. occidentalis*; each layer flattened near margin of shell (pl. 29, figs. 5, 7).

Ventral valve: Propareas narrow, not sharply defined; pedicle groove wide, shallow, short. Central portion of valve greatly thickened internally by massive callus deposit, which separates easily from outer shell

EXPLANATION OF PLATE 31

- FIGS. 1-9—"*Acrotreta*" *tetonensis* Walcott. 1, 2, 4, Hypotype; posterior, lateral, and apical views of ventral valve, Mont. T1199b, $\times 6$, loc. 44-2. 3, Hypotype; interior of ventral valve, showing strong cardinal muscular scars and deep visceral cavity, Mont. T1199a, $\times 6$, loc. 44-2. 5, Hypotype; posterior view of ventral valve, showing apical foramen, Mont. T1199f, $\times 10$, loc. 44-2. 6, 8, Hypotypes; interior of incomplete dorsal valve, and fragment occurring 2.2 mm. from it, presumably part of a dorsal septum, Mont. T1199c-d, $\times 10$, loc. 44-2. 7, Hypotype; apical view of partly exfoliated ventral valve, showing impression of visceral cavity, Mont. T1199g, $\times 15$, loc. 44-2. 9, Hypotype; exterior of incomplete dorsal valve, Mont. T1199e, $\times 10$, loc. 44-2. Upper Cambrian: Dry Creek shale. (p. 234)
- 10-14—*Prototreta subcircularis* Bell, n. sp. 10-12, Syntype; posterior, lateral, and apical views of ventral valve with slightly broken apex, Mont. T1187a, $\times 6$, loc. 26-4. 13, Syntype; exterior of dorsal valve, Mont. T1187b, $\times 6$, loc. 26-4. 14, Syntype; interior of incomplete dorsal valve, Mont. T1187c, $\times 6$, loc. 26-4. Middle Cambrian: Pentagon shale. (p. 228)
- 15-19—*Linnarssonella elongata* Bell, n. sp. 15, 16, Syntype; two views of ventral interior, the former tilted so as to show apical cavity, the latter showing strongly apsacline pseudo-interarea, Mich. 20811a, $\times 6$, loc. M-14. 17, Syntype; interior of dorsal valve, showing strongly developed apical platform, short septum, and deep grooves in posterolateral margins for reception of "teeth" in ventral valve, Mich. 20811b, $\times 6$, loc. M1-4. 18, 19, Syntypes; exteriors of dorsal and ventral valves, Mich. 20811d-e, $\times 6$, loc. M1-4. Upper Cambrian: Snowy Range formation. (p. 235)
- 20-23—*Prototreta attenuata* (Meek). 20-22, Hypotype; lateral, posterior, and apical views of incomplete ventral valve, U.S.N.M. 7867d, $\times 6$, loc. 302. 23, Paratype (Mon. 51, pl. 64, fig. 1h); exterior of badly exfoliated dorsal valve, U.S.N.M. 7867c, $\times 6$, loc. 302. Middle Cambrian: Meagher limestone (*Ehmania* zone). (p. 223)
- 24-33—*Prototreta mimica* Bell, n. sp. 24, 27, 28, Syntype; apical, posterior, and lateral views of ventral valve, Mont. T1188a, $\times 6$, loc. 47-3. 25, 26, Syntype; lateral and posterior views of gerontic ventral valve with strongly curved pseudointerarea, Mont. T1188g, $\times 6$, loc. 47-3. 29, 31, Syntypes; interiors of dorsal valves with expanded septa, Mont. T1188d-e, $\times 6$, loc. 47-3. 30, Figured specimen; interior of dorsal valve with unexpanded septum, probably the result of secondary reconstruction (see text fig. 13), Mont. T1188h, $\times 6$, loc. 47-3. 32, Syntype; exterior of dorsal valve, Mont. T1188b, $\times 6$, loc. 47-3. 33, Syntype; internal mold of dorsal valve, showing impressions of strong muscular scars, Mont. T1188c, $\times 6$, loc. 47-3. Middle Cambrian: Meagher limestone. (p. 226)
- 34-48—*Prototreta trapeza* Bell. 34, 35, 37, Paratype; posterior, lateral, and apical views of ventral valve, Mich. 20819a, $\times 6$, loc. M4-4. 38-40, Paratypes; interior views of three ventral valves, showing high ridge behind intertrough, internal opening of pedicle tube, and deep pallial sinuses, Mich. 20819f-g ($\times 8$, loc. M4-4), Mont. T1186a ($\times 6$, loc. 45-3a). 41, Paratype; interior view of anterior slope of ventral valve, showing projecting shell laminae, pallial sinuses, and apical cavity, Mich. 20819d, $\times 6$, loc. M4-4. 42, 43, Paratypes; exterior views of two dorsal valves, Mich. 20819b-c, $\times 6$, loc. M4-4. 44, 36, Figured specimen; interior of incomplete dorsal valve exposed by weathering, and part of anterior end of dorsal septum occurring 8 mm. distant on same piece of limestone, Mont. T1191a, $\times 6$, loc. 47-3 loose. 45, 47, 48, Paratypes; interior of three dorsal valves, showing variations in flabellate septum, and two pairs of cardinal muscular scars in 45, Mont. T1186c ($\times 6$, loc. 45-3), Mich. 20819e ($\times 6$, loc. M4-4), Mont. T1186b ($\times 6$, loc. 45-3a). 46, Holotype (Bell, 1938, pl. 1, fig. 4); interior of dorsal valve, Mont. 1535, $\times 6$, loc. 45-3a. Middle Cambrian: Meagher limestone (*Bathyriscus* zone). (p. 229)
- 49-58—*Prototreta flabellata* Bell, n. sp. 49-51, Syntype; apical, lateral, and posterior views of partly exfoliated ventral valve, Mich. 20805a, $\times 6$, loc. M3-2. 52, Figured specimen; exterior of partly exfoliated dorsal valve, Mont. T1190a, $\times 10$, loc. 43-3a. 53, Figured specimen; exterior view of dorsal valve, Mont. T1189b, $\times 6$, loc. 45-2. 54, Figured specimen; posterior view of ventral valve, showing pedicle foramen and narrow intertrough, Mont. T1189a, $\times 10$, loc. 45-2. 55, Figured specimen; enlarged view of anterior portion of valve in 53, showing criss-cross pattern in sulcus, and segmentation of fila, Mont. T1189b, $\times 10$, loc. 45-2. 56, Syntype; greatly magnified view of thin section made at expanded portion of dorsal septum (see text fig. 20, for serial sections), Mich. 20805c, ca. $\times 54$, loc. M3-2. 57, Figured specimen; enlarged view of middle portion of valve in 52, showing segmentation of fila, Mont. T1190a, ca. $\times 30$, loc. 43-3a. 58, Syntype; exterior of partly exfoliated dorsal valve, showing criss-cross pattern of fila in sulcus, Mich. 20805b, $\times 10$, loc. M3-2. Middle Cambrian: Meagher limestone (*Ehmania* zone). (p. 223)

laminae. Musculature not well enough known to warrant description.

Dorsal valve: Propareas not distinct. Central portion of valve thickened internally by massive callus deposit, which separates easily from outer shell laminae; callus concentrated in two wide arcuate ridges, convex toward lateral margins of valve, and bordering a pair of large muscular impressions, presumably the centrals.

	Dimensions (mm.)		
	Length	Width	L/W
Ventral valve:			
Mont. T1202b....	?	6.1?	
Dorsal valves:			
Mont. T1202a....	5.0?	6.5?	0.77
Mich. 20812a....	4.8?	6.0?	0.80

Holotype, Mont. T1202a; paratypes, Mont. T1202b-d; figured specimens, Mich. 20812a-b.

Horizon and locality.—Upper Cambrian. Dry Creek shale: 44-2, *Crowfoot Ridge*; 46-3, Nixon Gulch; U.S.N.M. localities 151a, Churn Canyon; 152a, Dry Creek; 158, near Hillsdale. Snowy Range formation: M1-4, Beartooth Butte; M2-1, Republic Mt.

Distinguishing characters.—*Dicellomus mosaica* is characterized by its large size, transversely ovate outline, moderate and subequal biconvexity, and surface ornamentation consisting of minute and closely adjacent pits.

Discussion.—*Dicellomus mosaica* apparently is very close to *D. pectenoides* (Whitfield) in size and form, but differs in having a pitted surface ornamentation. Most of the specimens from Montana that Walcott assigned to *D. pectenoides* are *D. mosaica*.

DICELLOMUS OCCIDENTALIS Bell, n. sp.

Plate 29, figures 18-23

Dicellomus politus (Hall). WALCOTT (part), 1912, U. S. Geol. Survey, Mon. 51, pl. 52, fig. 3.

Outline of ventral valve slightly elongate subtrigonal, greatest width being about 0.6 length of valve from apex; outline of dorsal valve slightly transverse subtrigonal to ovate, greatest width being slightly less than 0.6 length of valve from apex; profile strongly dorsi-biconvex, greatest convexity near middle of ventral valve and in posterior third of dorsal valve; surface usually glossy, smooth except for very subdued and indistinct growth ridges; shell thick, composed of

several laminae, of which the inner ones are radially banded and distinctly pitted; each layer abruptly flattened at margin of shell, conspicuous on partly exfoliated valves (pl. 29, figs. 19, 21).

Ventral valve: Interior like that of *D. politus* (Hall), so far as can be determined; cardinal muscular scars large, deep; composite central scar borders each side of spatulate visceral area near its anterior end.

Dorsal valve: Interior similar to that of *D. politus*; pedicle furrow shallow; postero-lateral grooves, as described for *D. politus* (Walcott, 1912, p. 577), not observed; cardinal muscular scars large, apparently composite; central scars large, elongate, near middle of valve, and separated by a low ridge; anterior lateral scars small, elongate, between and nearly in contact with anterior ends of central scars.

	Dimensions (mm.)		
	Length	Width	L/W
Ventral valves:			
Mont. T1200b....	5.1	5.0	1.02
Mont. T1200e....	5.8	5.75	1.01
Dorsal valves:			
Mont. T1200a....	4.1	4.5	0.91
Mont. T1200d....	4.5	5.0	0.90

Syntypes, Mont. T1200a-f.

Horizon and locality.—Upper Cambrian. Lower Pilgrim limestone: 32-3, *Belt Creek*; 33-1 (?), 33-2, Keegan Butte; 38-3, Dry Wolf Creek. Limestone lenses in upper Park shale: 38-1, Dry Wolf Creek; 41-3, Big Snowy Mountains. Lower Pilgrim limestone or limestone lenses in upper Park shale: U.S.N.M. localities 5k (2), head of Sawmill Creek; 302k, near Gallatin.

Distinguishing characters.—*Dicellomus occidentalis* is characterized by its subequal length and width, dorsi-biconvexity, abrupt outward flexing of shell layers to form a flat marginal brim, and by having the dorsal anterior lateral muscular scars nearly in contact with the central scars.

Discussion.—*Dicellomus occidentalis* differs from *D. politus* (Hall) in having a less elongate and acuminate ventral valve, a more transverse and convex dorsal valve, the dorsal valve being more convex than the ventral, and in the position of the dorsal anterior lateral muscular scars.

The type specimens of *D. nanus* (Meek and Hayden) from the Black Hills of South

Dakota, although so poorly preserved as to be almost useless for comparison, seem to be closer to *D. politus* than to *D. occidentalis*. Walcott's (1912, p. 573, pl. 53, figs. 1, 1a-l) presentation of *D. nanus* was based on excellently preserved specimens from the Big-horn Mountains, Wyoming, which may not belong to *Dicellomus*; the shell is evidently composed of only one thick layer, instead of being made up of numerous radially banded laminae as in the genotype of *Dicellomus*.

Genus ACROTHELE Linnarsson, 1876

ACROTHELE CLARKI (Walcott)

Plate 30, figures 4-7

Dearbornia clarki WALCOTT, 1908, Smithsonian Misc. Coll., vol. 53, no. 3, p. 78, pl. 8, fig. 7;—1912, U. S. Geol. Survey, Mon. 51, p. 614, pl. 82, figs. 7, 7a-d.

Walcott's assignment of this species to a new genus, *Dearbornia*, was unquestionably the result of his interpretation of the shell substance as being calcareous. The original collection comprises the only specimens of the species known, but a restudy of them forces the conclusion that the shell material was calcareoconchous. There are no "semi-phosphatic shells of *Obolus*" (Walcott, 1912, p. 614) associated with the type specimens in the coarsely oolitic limestone matrix. The holotype, a ventral internal mold, has at the apex a remnant of the original shell, enclosing a mold of the interior of the pedicle tube (pl. 30, fig. 6). The fragment is black, hard, and glossy, being typical of the shell substance of *Acrothele*. Most of the specimens obviously are internal molds; in a few individuals the original shell apparently was dissolved, and the resulting cavity filled with calcite. Probably it was these specimens on which Walcott based his interpretation of a calcareous shell.

The internal molds reveal a morphology congeneric with *Acrothele*. In the dorsal valve there is clearly indicated an umbonal thickening and two narrow ridges extending anterolaterally from it (pl. 30, fig. 5). The ventral valve possesses the short pedicle tube and strong pallial trunks characteristic of the genotype and other species of *Acrothele*.

Acrothele clarki cannot be adequately compared with other species of *Acrothele* from Montana, but it appears to differ from all of them in being smaller, more elongate in

outline, and in having the ventral apex near the posterior margin.

Dimensions (mm.)

	Length	Width	L/W
Ventral valves:			
U.S.N.M. 52214a.	3.0	3.0	1.00
U.S.N.M. 52214c.	5.25	5.25	1.00
Dorsal valve:			
U.S.N.M. 52214d.	4.0	3.9	1.03

Holotype, U.S.N.M. 52214a; paratypes, U.S.N.M. 52214b-d.

Horizon and locality.—Middle Cambrian. U.S.N.M. loc. 9k, Dearborn Canyon section; exact stratigraphic position unknown, possibly Damnation limestone.

ACROTHELE COLLENI Walcott

Plate 30, figures 1-3

Acrothele colleni WALCOTT (part), 1912, U. S. Geol. Survey, Mon. 51, p. 640, pl. 63, figs. 6, 6a-b (not text figs. 55A-E, p. 641); WALCOTT (part), 1917, Smithsonian Misc. Coll., vol. 67, no. 2, pl. 4, figs. 5d-f.

Outline probably subcircular, with posterior margin of ventral valve slightly truncated; growth ridges on surface irregularly spaced, faint to rugose; entire surface covered by minute, irregular, inosculating ridges, bearing papillae on their crests. Shell calcareoconchous, laminated, thick.

Ventral valve: Profile triangular, height excessive for the genus; apex slightly posterior to middle of shell, bluntly rounded, bearing a pair of elongate tubercles on well-preserved valves; foramen elongate-elliptical, situated posterior to apex; posterior slope flattened, surface of apical half granular, that of marginal half smooth. Interior has a low tubercle, its lateral surface concave, on either side of median line about middle of posterior slope; low projecting ridge or collar constricts small apical chamber.

Dorsal valve: Apex marginal, minute, depressed, formed by two elongate tubercles; umbo convex, with broad and deep basinlike preumbonal depression; anterior two-thirds of valve flat or slightly convex. Interior unknown.

Holotype, U.S.N.M. 51973a; paratypes, U.S.N.M. 51973b-c; hypotype, U.S.N.M. 51973d.

Horizon and locality.—Middle Cambrian. Gordon shale; U.S.N.M. loc. 4q, ridge between Gordon and Youngs Creeks.

Distinguishing characters.—*Acrothele col-*

	Dimensions (mm.)			
	Length	Width	Height	L/W H/W
Ventral valve:				
U.S.N.M. 51973b.....		6.5	2.2?	0.34
Dorsal valve:				
U.S.N.M. 51973d.....	7.0	7.0		1.00

leni is characterized by its excessively high, subconical ventral valve and by the large preumbonal depression in the dorsal valve.

Discussion.—The holotype, a ventral valve, is so badly damaged that a better preserved paratype (Walcott, 1912, pl. 63, fig. 6a) is refigured in this paper (pl. 30, figs. 1–2). The dorsal valve illustrated by Walcott (1912, pl. 63, fig. 6b) is an external impression that does not show the apex clearly; an associated valve, a hypotype, is figured in this paper (pl. 30, fig. 3).

Acrothele colleni is readily distinguished from all other species of *Acrothele* in Montana by its high ventral valve and preumbonally depressed dorsal valve. The specimens from British Columbia and Alberta (Walcott, 1912, pp. 641–42) do not belong to this species.

Some ventral valves suggest that the marginal half of the posterior slope is bulged into a “homoeodeltidium,” much like that in *Micromitra sculptilis* (Meek), but this condition may be the result of crushing. Slots in the posterior margin of a paratype (pl. 30, figs. 1–2) may be of secondary origin, although their bilaterality suggests that they may be primary structures.

ACROTHELE PANDERI Walcott

Plate 30, figures 15–18

Acrothele panderi WALCOTT, 1912, U. S. Geol. Survey, Mon. 51, p. 651, pl. 59, figs. 5, 5a–c.

Outline subcircular to transversely subelliptical; growth ridges faint to moderately strong, unequally spaced; entire surface covered by closely spaced coarse granules; shell calcareoconeoous, laminated, moderately thick.

Ventral valve: Profile obtusely trigonal; apex low, formed by two elongate tubercles, situated close to posterior margin in young individuals, nearer to middle third of valve in mature specimens; foramen elongate elliptical, situated posterior to apex; pseudo-interarea modified by triangular, smooth, slightly convex portion occupying marginal two-thirds of slope, and bounded by abrupt

flexure of fila along two lines, which diverge posteriorly at an angle of about 45°. Interior unknown.

Dorsal valve: Outline somewhat subquadrate as result of slight straightening of anterior and posterior margins; profile very slightly convex; apex marginal, minute, depressed, formed by two elongate tubercles; sulcus distinct or vague, deeper and wider toward margin of valve, usually with low secondary ridges on floor. Interior with umbonal callosity, from which two subarcuate ridges extend anterolaterally. This structure is like that in *A. pentagonensis* but less strongly developed (compare pl. 30, fig. 18, and pl. 30, fig. 9).

	Dimensions (mm.)		
	Length	Width	L/W
Ventral valves:			
U.S.N.M. 52003a.	3.2	3.4	0.94
U.S.N.M. 52002c.	8.3?	10.0?	0.83
Dorsal valves:			
U.S.N.M. 52003b.	4.0	4.5	0.89
U.S.N.M. 52002d.	8.0	8.5?	0.94

Holotype, U.S.N.M. 52003a; paratypes, U.S.N.M. 52003b, 52002a–b; hypotypes, U.S.N.M. 52002c–d.

Horizon and locality.—Middle Cambrian. Gordon shale: U.S.N.M. localities 4v, Gordon Creek; 5j, Scapegoat Mountain.

Distinguishing characters.—*Acrothele panderi* is characterized by its coarsely granular surface, sulcate dorsal valve, and very low ventral valve.

Discussion.—*Acrothele panderi* apparently is most similar to *A. pentagonensis*, but differs distinctly from it in having a dorsal sulcus and a coarsely granular surface.

The holotype of *A. panderi* evidently is an immature individual. The revised description of the species is based primarily on large ventral valves from a locality not far distant from the type locality. The dorsal sulcus is a somewhat variable feature, although always present. Valves with distinct and indistinct sulci are present at both localities from which the species is known. Most of the dorsal valves from locality 5j are

cracked longitudinally at the apex, which accounts for the linear ridge visible on the internal molds. No ventral interiors were found by the writer in the collections at the United States National Museum, and consequently the characters described by Walcott (1912, p. 651) could not be verified.

ACROTHELE PENTAGONENSIS Bell, n. sp.

Plate 30, figures 8-10

Outline subcircular; growth ridges strong, regularly spaced, distinctly more rugose towards margin of shell; entire surface covered by irregularly undulating and broken threadlike elevations, bearing numerous minute papillae upon their crests. Shell calcareoconeous, laminated, thick.

Ventral valve: Profile obtusely trigonal; pseudointerarea straight, about 55° procline, approximately one-third length of gently concave anterior slope; pseudointerarea smooth, except for growth ridges, and indistinctly bounded by abrupt flexing of growth ridges along two lines, which diverge from foramen at about 60°; triangular fold on anterior slope produced by several low ridges, which radiate from apex, widen, and partly fuse toward margin of valve; angle of divergence between two lateral ridges about 45°; apex rounded, formed by two large round tubercles; foramen large, elongate-elliptical, situated posterior to apex. Interior unknown.

Dorsal valve: Profile gently convex, greatest convexity slightly anterior to apex; apex marginal, depressed, formed by two large elongate tubercles. Interior with small crenulated space at apex, probably for muscular attachment; strong umbonal thickening present, extends anteriorly as a low narrow ridge, which forks around a short median furrow (muscular scar), the two prongs disappearing opposite middle of furrow; umbonal thickening extended anterolaterally as two short ridges, which are concave outwardly (pl. 30, fig. 9).

Dimensions (mm.)

	Length	Width	L/W
Dorsal valve:			
Mont. T1196b....	9.0?	10.0	0.90

Syntypes, Mont. T1196a-c.

Horizon and locality.—Middle Cambrian. Pentagon shale: 26-4, Lick Creek.

Distinguishing characters.—*Acrothele pentagonensis* is characterized by its triangular ventral fold, smooth ventral pseudointerarea, and surface ornamentation.

Discussion.—*Acrothele pentagonensis* resembles *A. panderi* to some degree but differs from it in having a ventral fold and in not having a dorsal sulcus. Also, the surface ornamentation in the two species is quite different. *A. pentagonensis* resembles rather closely *A. asiatica* Resser and Endo (1937, p. 128, pl. 25, figs. 6-10) from the Mapan formation of southern Manchoukuo, but, so far as can be determined from a comparison of their morphology, appears to be specifically different.

A. panderi and *A. colleni* differ from *A. pentagonensis* in having the apical third of the posterior slope (pseudointerarea) granulated in the same manner as the general surface of the shell, and in having the marginal two-thirds smooth. The significance of this difference is not known.

Genus *PROTOTRETA* Bell, 1938

Prototreta BELL, 1938, Michigan Acad. Sci., Papers, vol. 23, p. 405.

Outline subcircular, subtrapezoidal, or transversely subelliptical; ventral valve conical, dorsal valve slightly convex; anterior commissure rectimarginate or sulcate; shell minute, calcareoconeous, laminated, surface filate.

Ventral valve: Posterior margin indented at midpoint; profile subtriangular; pseudointerarea procline to apsacline, depressed at center, forming a trough (intertrough) which widens and deepens from apex to margin of valve; bottom of trough characterized by a flattened granular area, extending from foramen to commissure; foramen circular, situated posterior to apex. Shell laminae in apical portion of valve project into interior, forming an imperfect "cone-in-cone" structure; pedicle tube has internal opening at about midpoint of a low ridge, which extends from apex to center of posterior margin; deep pit, from which a narrow pallial sinus extends anterolaterally, occurs on either side of ridge, opposite opening of pedicle tube.

Dorsal valve: Apex minute, marginal, grooved at summit, extended beyond margin of ventral valve; sulcus present or ab-

sent. Posterolateral margins thickened into nearly flat, anacline propareas, which border a broad central groove whose margins diverge anteriorly from apex at about 90°, prominent median septum expands anteriorly into a plate, from which extend finger-like projections; a pair of small muscular scars adjoins posterior end of septum; each large scar of a pair lateral to the first is elongated in line with margin of apical groove; a possible third pair occurs on floor of valve adjoining expanded portion of septum.

Genotype, *Prototreta trapeza* Bell, 1938.

Distinguishing characters.—The most characteristic structure possessed by this genus is the flabellate dorsal septum. The "cone-in-cone" character of the ventral valve, the troughlike ventral pseudointerarea with its central granular floor, the circular foramen posterior to the apex, and the triangular dorsal propareas further distinguish *Prototreta* from all other described genera.

Discussion.—*Prototreta* belongs to a large group of species that have been assigned, on the basis of external similarity, to the genus *Acrotreta* Kutorga. The writer (1938, p. 403) has discussed somewhat at length the status of *Acrotreta* and the reasons for separating new genera from it. Briefly, the internal characters of the genotype, an Ordovician species from the Baltic region, are unknown. Because it appears that several generic groups are included among the species now assigned to *Acrotreta*, it is desirable to describe these groups and determine their relationship to *Acrotreta* s.s. when the internal characters of the latter are made known.

The internal characters of most American species of "*Acrotreta*" are unknown, and consequently their generic status is in doubt. Until the anatomy of these so-called species of *Acrotreta* are known, little can be said regarding the systematic relationships of *Prototreta*. However, a few of the characters of *Prototreta* which may be important in the determination of generic relationship should be emphasized.

The thin laminae of the shell of *Prototreta* project into the interior of the ventral valve, simulating an incomplete "cone-in-cone" structure (pl. 31, fig. 41; text figs. 7, 15, 18). Because the inner ends of the laminae are

embedded in matrix, any attempt to exfoliate the shell in order to obtain an internal mold is unsatisfactory. Some valves can be cleaned with a needle, but the more delicate inner extensions of the laminae are destroyed, and with them any pallial or muscular markings that they may possess. This extreme development of a "cone-in-cone" structure is not apparent in any described species of "*Acrotreta*" seen by the writer, although a few appear to possess it to a slight degree in the apical portion of the valve.

The so-called "false pedicle groove" on the posterior slope of the ventral valve almost certainly was unrelated to the functional pedicle, but it may represent the growth track of the internal pedicle tube during development of the valve. The term *intertrough* is proposed for this furrow, which depresses the posterior slope from the apex to the commissure in many acrotretoid brachiopods. So far as can be observed, no opening was present between the valves at the cardinal margin. Evidently a thickened projection of the ventral valve fitted into the apical groove in the dorsal valve.

The type of dorsal pseudointerarea characteristic of *Prototreta* apparently has not been described in the literature, but a study of several species of "*Acrotreta*" suggests that careful preparation may reveal its presence. Seemingly the strongly anacline propareas, which extend into the ventral valve, would prohibit any pronounced lateral sliding of the valves over each other, such as is generally thought to occur among the "inarticulate" brachiopods. The median groove which simulates the ventral pedicle groove of certain atremate brachiopods, appears to have been the seat of muscular implantation. The markings in the groove, together with the faint median ridge, produce a structure analogous, if not homologous, with that in some articulate brachiopods which do not possess a cardinal process.

The flabellate dorsal septum, the most characteristic structure of *Prototreta*, apparently is unique among brachiopods. Considerable variation, even within the same species, is apparent (pl. 31, figs. 45-48), but because the septum can be completely exposed only under very favorable conditions, and even then at the expense of considerable time, no systematic study of the structure

could be undertaken. The function of the septum is a matter of speculation. Schuchert⁶ and Cooper⁶ believe it to be the seat of muscular attachment. This appears to be the best explanation, even though muscular scars have not been observed on the septum. The septum in *P. trapeza* and *P. subcircularis* is much stronger and apparently more specialized than it is in the somewhat earlier *P. flabellata* and *P. mimica*.

Muscular scars have been positively identified on the floor of the valve adjacent to the propareas. One pair of small scars adjoins the posterior end of the septum, and two larger scars, lateral to the first, diverge anterolaterally almost in line with the margins of the apical groove. A third pair of questionable muscular impressions adjoins the septum near its middle. Although the points of insertion of some of the muscles are known, no statement can be made regarding the arrangement of the muscles and their operation.

PROTOTRETA ATTENUATA (Meek)

Plate 31, figures 20-23

Acrotreta attenuata MEEK, U. S. Geol. and Geol. Survey Terr., Sixth Ann. Rept. p. 463, footnote; WALCOTT (part), 1912, U. S. Geol. Survey, Mon. 51, p. 675, pl. 64, figs. 1, 1a, 1h (not figs. 1b-g=*Prototreta flabellata* Bell, n. sp.; figs. 1i-o).

Acrotreta attenuata var.? WALCOTT, 1905, U. S. Nat. Mus., Proc., vol. 28, p. 298; 1912, U. S. Geol. Survey, Mon. 51, p. 676, pl. 65, fig. 2.

This species is not represented in the writer's collections, the present discussion being based on the type lot of specimens preserved in the United States National Museum.

The apex of the holotype (Walcott, 1912, pl. 64, fig. 1), a ventral valve, is broken, and most of the shell has been exfoliated from the pseudointerarea. The growth lines are similar to those on *Prototreta trapeza*, perhaps slightly more distinct and regular, except that they are crinkled into a "criss-cross" pattern along the midline of the anterior slope. A nearly complete ventral valve (Walcott, 1912, pl. 64, fig. 1a) shows all the

external characters of *Prototreta* and is unquestionably conspecific with the holotype but does not have the crinkled growth lines on the anterior slope. A third valve (Walcott, 1912, pl. 64, fig. 1h), a dorsal, gives little information other than the outline. A single ventral valve from the same locality was identified by Walcott (1912, p. 676, pl. 65, fig. 2) as *Acrotreta attenuata* var.?, but it appears not to be distinct from the species. Three other lots of specimens, almost certainly from the type locality but not numbered, contain several nicely preserved ventral valves of "*Acrotreta*" *attenuata*, one ventral valve of *Prototreta flabellata*, and two dorsal valves referred to *Prototreta flabellata*. In addition, specimens of *Micromitra* and "*Lingulella*" too poorly preserved to be specifically determined and a single pygidium of *Ehmania*, are present. The aspect of the fauna places it in the basal Meagher *Ehmania* zone, but *Prototreta attenuata* does not occur in any of the writer's collections from that zone.

Because the dorsal valve figured by Walcott (1912, pl. 64, fig. 1h) is the only one known, and because it does not give information of the interior, the present assignment of this species to *Prototreta* cannot be definitely proved. However, the information revealed by the ventral valves alone seems sufficient to make the assignment with considerable confidence.

Prototreta attenuata is characterized by its sharply pointed apex, straight pseudointerarea, and strongly concave slope slightly anterior to the apex.

Holotype, U.S.N.M. 7867a; paratypes, 7867b-c; hypotype, 7867d.

Horizon and locality.—Middle Cambrian. Meagher limestone (*Ehmania* zone?): U.S. N.M. loc. 302, east side of West Gallatin River, above Gallatin.

PROTOTRETA FLABELLATA Bell, n. sp.

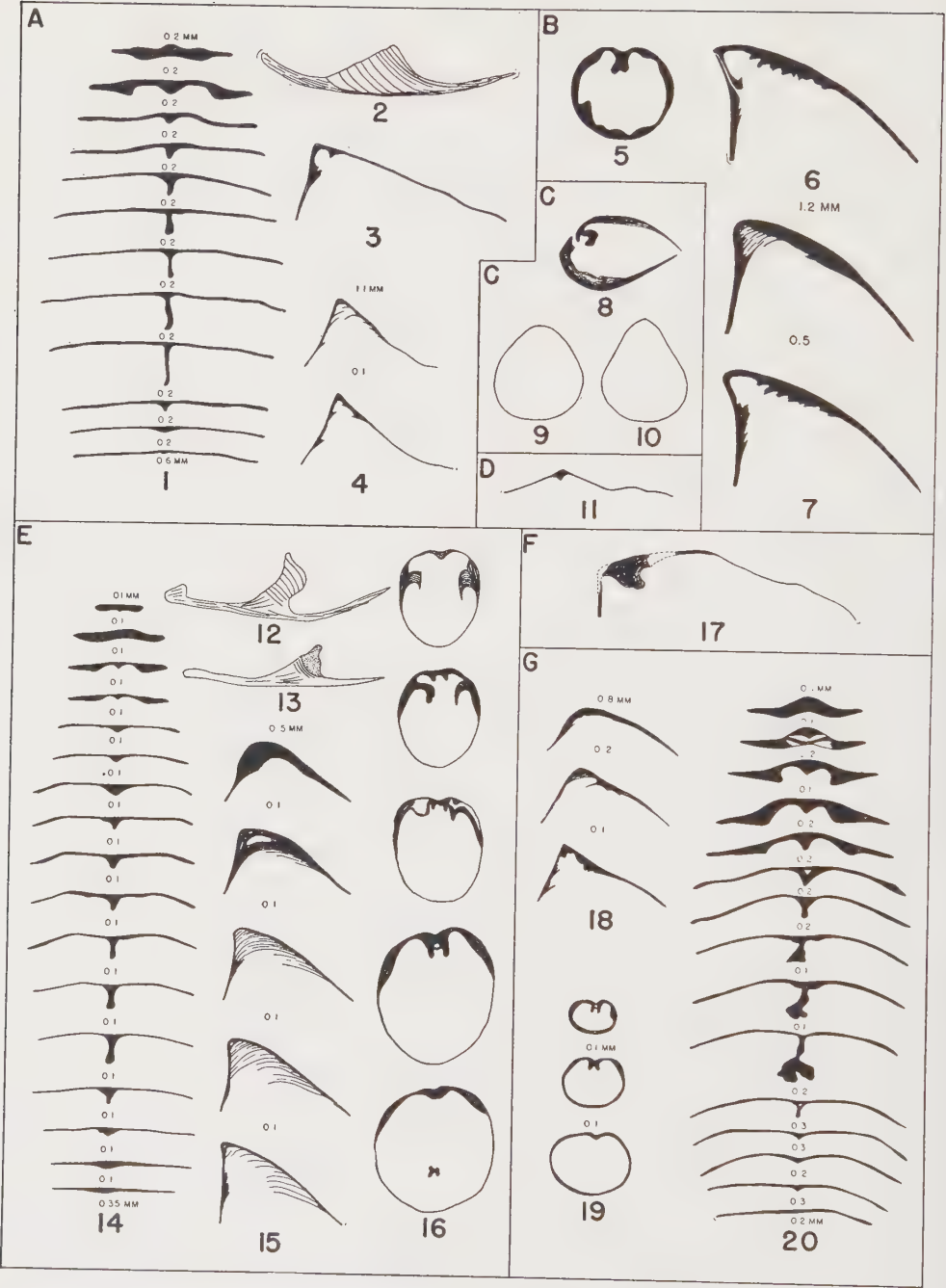
Plate 31, figures 49-58;
text figures 18-20

Outline subcircular or transversely subel-

Dimensions (mm.) of *Prototreta attenuata*

	Length	Width	Height	L/W	H/W
Ventral valve:					
U.S.N.M. 7867d.....	2.0?	2.25?	1.6	0.89	0.71
Dorsal valve:					
U.S.N.M. 7867c.....	2.9	3.17		0.91	

⁶ Personal communications.



FIGS. 1-20.—Cross sections of Cambrian Brachiopoda. For detailed explanation see opposite page.

liptical; ventral valve conical and lower than average for genus; dorsal valve slightly convex and gently sulcate; fila strong, regular, rounded, usually continuous, but segmented on the marginal portions of some valves (pl. 31, fig. 57).

Ventral valve: Posterior margin indented at base of intertrough, anterior margin straight or slightly emarginate; profile subtriangular; pseudointerarea straight, 10°–

20° procline; anterior slope straight or gently convex, often tending to be slightly concave near apex; intertrough wider and deeper at commissure than at foramen, and characterized by medial, well-defined, distinctly depressed and flattened granular area, the sides of which tend to be subparallel; foramen circular, about 0.03 mm. in diameter, and situated slightly posterior to apex; fila flex apically along margins of posterior gran-

EXPLANATION OF TEXT FIGURES 1–20

FIGS. 1–4—*Homotreta interrupta* Bell, n. gen., n. sp. 1, Syntype; serial sections from apex to anterior margin of dorsal valve, showing bladelike septum (see pl. 30, fig. 26, for photograph of thin-section taken at highest point of septum), Mont. T1194g, loc. 26-3. 2, Syntype; profile of dorsal septum, showing trend of growth lines, Mont. T1194e, loc. 26-3. 3, Syntype; section through longitudinal midplane of ventral valve, Mont. T1194h, loc. 26-3. 4, Figured specimen; sections parallel to longitudinal midplane of ventral valve, unnumbered specimen, loc. 26-2. Middle Cambrian: "Pagoda" limestone. (p. 230)

5–7—*Prototreta trapeza* Bell, 5, Paratype; cross section through ventral valve, taken parallel to commissure and about at middle of posterior slope, showing high internal ridge behind intertrough (see pl. 31, fig. 39, for specimen from which drawing was made), Mich. 20819g, loc. M4-4. 6, Theoretical composite cross section along longitudinal midplane of ventral valve, showing probable trend of pedicle tube. 7, Paratype; longitudinal sections through ventral valve, showing "cone-in-cone" structure of shell laminae (lower section is along midline of valve), Mich. 20819h, loc. M4-4. Middle Cambrian: Meagher limestone (*Bathyriscus* zone). (p. 229)

8–10—*Linnarssonella elongata* Bell, n. sp. 8, Syntype; drawing of thin section taken parallel to longitudinal axis of complete specimen, but slightly to one side, showing structure for articulation (ventral valve below), Mich. 20811c, loc. M1-4. 9, 10, Syntypes; outlines of dorsal and ventral valves shown, respectively, on pl. 31, figs. 18 and 19, Mich. 20811d–e, loc. M1-4. Upper Cambrian: Snowy Range formation. (p. 235)

11—*Pegmatreta perplexa* Bell, n. gen., n. sp. Figured specimen; longitudinal section along midplane of ventral valve, showing thickened apex (posterior margin at left), unnumbered specimen, loc. M4-4. Middle Cambrian: Meagher limestone (*Bathyriscus* zone). (p. 232)

12–16—*Prototreta mimica* Bell, n. sp. 12, Syntype; longitudinal profile of expanded type of dorsal septum, drawn from thin section (trend of growth lines represented diagrammatically), Mont. T1188f, loc. 47-3. 13, Figured specimen; profile of an unexpanded septum, probably the result of secondary inorganic growth of a broken expanded type of septum, drawn from specimen shown on pl. 31, fig. 30 (trend of growth lines represented diagrammatically; stippled portion composed of translucent homogeneous calcite), Mont. T1188h, loc. 47-3. 14, Figured specimen; serial sections from apex to anterior margin of dorsal valve, showing what appears to be an unexpanded septum, a condition that may be the result of breakage of an expanded septum during fossilization, unnumbered specimen, loc. 47-3. 15, Figured specimen; serial sections through a ventral valve parallel to the longitudinal axis and perpendicular to the commissure, showing "cone-in-cone" structure of the shell laminae (bottom section through midplane of valve), unnumbered specimen, loc. 47-3. 16, Figured specimen; sketches of a series of sections through a ventral valve parallel to commissure, showing high internal ridge behind intertrough, with pedicle tube within it; bottom sketch shows highest portion of expanded septum in dorsal valve of the complete specimen (distance between sections unknown), unnumbered specimen, loc. 47-3. Middle Cambrian: Meagher limestone. (p. 226)

17—*Pegmatreta rotunda* Bell, n. gen. n. sp. Syntype; drawing of a thin section along longitudinal midplane of ventral valve, showing greatly thickened apex and trend of growth lines, Mont. T1195e, loc. 26-3. Middle Cambrian: "Pagoda" limestone. (p. 232)

18–20—*Prototreta flabellata* Bell, n. sp. 18, Figured specimen; serial sections through ventral valve parallel to longitudinal axis and perpendicular to commissure (bottom section along midplane of valve), unnumbered specimen, loc. M4-3. 19, Figured specimen; serial sections through a ventral valve parallel to commissure, showing high internal ridge behind intertrough, with pedicle tube within it, unnumbered specimen, loc. M4-3. 20, Syntype; serial sections from apex to anterior margin of dorsal valve, showing flabellation of expanded septum (see pl. 31, fig. 56, for photograph of thin section made at point of greatest expansion of septum), Mich. 20805c, loc. M3-2. Middle Cambrian: Meagher limestone (*Ehmania* zone). (p. 223)

ular groove, often crinkled slightly on each flank of intertrough along a line from apex to posterolateral commissure. Interior apparently similar to that of *P. trapeza*, so far as can be determined.

Dorsal valve: Posterior margin slightly depressed at midpoint; apex marginal, with minute longitudinal groove or pit at summit, and projecting slightly beyond margin of ventral valve; umbo swollen, sharply raised above surfaces lateral to it; profile evenly and gently convex; anterior margin somewhat straightened, broadly and gently sulcate; fila in bottom of sulcus of most specimens bent toward apex, broken, and crinkled into a "criss-cross" pattern (pl. 31, fig. 55). Interior varies from that of *P. trapeza* only in minor respects; pseudointerarea typically somewhat narrower than that in the genotype, the margins of apical groove diverging at more than 90°; median septum similar, but expanded plate and projecting processes smaller and more delicate and consequently badly distorted or broken in fossilized valve; cardinal muscular scars deeply incised in most valves.

very soft shale, in which valves are fragmental and badly crushed. So far as can be ascertained, the species is very similar internally to *P. trapeza*, although apparently the structures in *P. flabellata* are somewhat more primitive and subject to greater individual variation. (See section on Homoeomorphism, p. 197, for discussion of *P. flabellata* and *Homotreta interrupta*.)

PROTOTRETA MIMICA Bell, n. sp.

Plate 31, figures 24-33;
text figures 12-16

Outline subcircular or transversely sub-elliptical; ventral valve sharply conical and high relative to its width; dorsal valve slightly convex and faintly sulcate; surface finely and closely filate, the fila blending laterally and longitudinally with adjoining fila; shell calcareoconeous, laminated, thin.

Ventral valve: Posterior margin gently indented at base of intertrough; profile subtriangular; pseudointerarea catacline, straight to strongly concave, with apex projecting distinctly beyond posterior margin; anterior slope more or less evenly convex,

Dimensions (mm.) of *Prototreta flabellata*

	Length	Width	Height	L/W	H/W
Ventral valve:					
Mich. 20805a.....	2.25	2.6	1.17	0.87	0.45
Dorsal valves:					
Mich. 20805b.....	2.4	2.75		0.87	
Mont. T1189b.....	2.75	3.0?		0.92	
Mont. T1190a.....	1.6	1.9		0.84	

Syntypes, Mich. 20805a-c; figured specimens, Mont. T1189a-b, T1190a.

Horizon and locality.—Middle Cambrian. Meagher limestone (*Ehmania* zone): 43-3a, Crowfoot Ridge; 45-2, M4-3, Nixon Gulch; M3-2, Pole Creek; U.S.N.M. localities 4n, head of Jackson Creek, Teton Mountains, Wyoming; 9h, Beaver Creek; 156a, near Hillsdale; 159, north of West Gallatin River.

Distinguishing characters.—*Prototreta flabellata* is characterized by its low, conical ventral valve, straight ventral pseudointerarea, strong rounded fila (segmented in some individuals), and delicate expanded dorsal septum.

Discussion.—Most of the specimens of *P. flabellata* were found in limestone and their internal morphology was studied principally from serial sections (text figs. 18-20). Some specimens from Nixon Gulch occur in a

sometimes concave just anterior to apex; intertrough slightly wider and deeper at commissure than at foramen, its floor scarcely flattened, and characterized by strengthening and fusion of fila; foramen minute and inconspicuous, situated on posterior face of sharply pointed apex; fila flexed apically and enlarged by fusion on sides of intertrough. Interior essentially as in *P. trapeza*, except that "cone-in-cone" lamellar structure is developed in all but marginal part of valve (text fig. 15), and posterior median ridge is not as strong.

Dorsal valve: Posterior margin slightly depressed at midpoint; apex marginal, with minute longitudinal groove or pit at summit, and projecting slightly beyond margin of ventral valve; umbo swollen, slightly raised above surfaces lateral to it; profile nearly flat or slightly convex; anterior margin of

most specimens gently sulcate; sulcus broad and shallow, disappearing before reaching apex; fila crossing sulcus without interruption. Interior like that of *P. trapeza* except for configuration of median septum; septum strong and bladelike, and in anterior third of valve spreading into a short, transverse, rodlike plate with projecting processes.

Dimensions (mm.)

	Length	Width	Height	L/W	H/W
Ventral valves:					
Mont. T1188a.....	2.1	2.4	1.7	0.88	0.71
Mont. T1188g.....	2.7	3.0	1.8	0.90	0.60
Dorsal valves:					
Mont. T1188b.....	2.4	2.7		0.89	
Mont. T1188c.....	3.0	3.4		0.88	

Syntypes, Mont. T1188a-g; figured specimen, Mont. T1188h.

Horizon and locality.—Middle Cambrian. Lower Meagher limestone: 47-3, Beaver Creek.

Distinguishing characters.—*Prototreta mimica* is characterized by its subcircular outline, high ventral valve with predominantly evenly convex anterior slope, uninterrupted fila in a faint dorsal sulcus, and dorsal septum expanded abruptly into a transverse rodlike plate.

Discussion.—*Prototreta mimica* differs from *P. trapeza* in outline, configuration of the dorsal septum, and in the absence of crinkled growth lines in the shallow dorsal sulcus; from *P. attenuata*, so far as can be determined, only in the lateral profile of the ventral valve.

The validity of the assignment of this species to *Prototreta* is dependent on whether the species is characterized by an expanded septum, i.e., one in which a transverse plate with anteriorly projecting processes is developed, or an unexpanded septum, i.e., one which consists of a simple vertical plate. Evidence has been observed for the presence of both types of septa, but the writer hopes in the following discussion to demonstrate that the evidence for an unexpanded septum is subject to serious question.

The investigation of the internal morphology of this species was hampered by an insufficient number of dorsal valves, all of which were embedded in a particularly untractable, nearly lithographic limestone matrix. They seem to be identical externally, but serial sections and prepared interiors

reveal what appear to be two types of internal septa. Two prepared valves (pl. 31, figs. 29, 31) show a narrow bladelike septum, which spreads abruptly into a transverse rodlike plate with projecting processes in the anterior third of the valve. A specimen (text fig. 16) in which the valves were joined as in life also revealed an expanded type of sep-

tum when sectioned. In contrast to the preceding three specimens, a single prepared dorsal valve (pl. 31, fig. 30; text fig. 13) possesses a simple vertical septum, which projects anteriorly as a single spike. Two serial sections (text fig. 14) likewise seem to show unexpanded septa, but the evidence from these sections must be accepted cautiously because, although the presence of features in the sections is proof of their presence in the valves, their absence from the sections proves only their absence from the valves at the time the sections were made and does not indicate whether that absence is the result of nondevelopment of the feature, or the result of subsequent removal of it through damage to the valve. The possibility of losing critical features in the spaces (0.1 mm.) between sections must not be overlooked.

As the presence or absence of an unexpanded septum in *P. mimica* cannot be proven from the two serial sections, the solution of the question rests on the evidence from the prepared dorsal valve (pl. 31, fig. 30) mentioned above. However, examination of this specimen under high magnification indicates that the septum has been altered subsequent to its original formation. The posterior part of the septum (text fig. 13) is composed of black opaque shell material like that forming the septa in the other two prepared dorsal valves of *P. mimica*. The anterior part, including the projecting spike, is translucent and apparently homogeneous in its physical composition, showing no lines of growth as have been observed in other septa of *P. mimica* (text fig. 12) and in

Homotreta interrupta (text fig. 2). To the writer it appears not to be a part of the original septum, but a later accretion of inorganic origin. Petrographic examination of the shell material in *Prototreta* and *Homotreta* shows it to be almost entirely secondary calcite, which apparently has completely replaced the structure of the original shell material (pl. 31, fig. 56; pl. 30, fig. 26). The dorsal septum behaves optically as a single calcite crystal, the c-axis being parallel to the long axis of the septum. As a tentative explanation for the peculiar structure of the unexpanded septum under discussion, the writer suggests that perhaps the original septum, of the expanded type, was broken before burial of the valve, and that during the subsequent process of petrification the broken septum was extended anteriorly as a spike by the addition of calcite, the final form of the addition being at least partly controlled by the unicrystalline character of the base from which it grew. Thus the final form of the structure, although the result of both organic and inorganic processes, simulates a septum of purely organic origin.

The septum of *P. mimica* is interpreted by the writer as having a transverse expansion of its highest part, making the species congeneric with *P. trapeza*, although the possibility of two types of septa in otherwise identical valves must be considered; until a more thorough study of the species is made possible by the collection of more specimens, the problem cannot be finally settled.

Ventral valve: Posterior margin strongly indented at base of intertrough; profile subtriangular; pseudointerarea about 25° procline, straight or slightly concave; anterior slope concave near apex, convex or straight near margin; intertrough wider and deeper at commissure than at foramen, and characterized by medial well-defined, more or less depressed and flattened triangular granular area; foramen circular, about 0.03 mm. in diameter, situated slightly posterior to apex; fila flexed apically and enlarged by fusion along margins of posterior granular groove. Interior like that of *P. trapeza*, so far as can be determined.

Dorsal valve: Posterior margin slightly depressed at midpoint; apex marginal, with minute longitudinal groove or pit at summit, and projecting slightly beyond margin of ventral valve; umbo swollen, sharply raised above surfaces immediately lateral to it; anterior margin rectimarginate or very faintly sulcate; fila bent toward apex along median line, broken, and crinkled into a faint "criss-cross" pattern. Interior varies only in minor respects from that of *P. trapeza*; pseudointerarea typically somewhat narrower and more delicate than that of the genotype; median septum similar in all respects except that triangular plate and anteriorly projecting processes are developed horizontally and close to floor of valve instead of projecting sharply beyond plane of commissure; "cardinal" muscular scars clearly visible in most valves.

Dimensions (mm.) of Prototreta subcircularis

	Length	Width	Height	L/W	H/W
Ventral valve:					
Mont. T1187a.....	2.25	2.7	1.5	0.83	0.56
Dorsal valve:					
Mont. T1187b.....	2.5	2.8		0.89	

PROTOTRETA SUBCIRCULARIS Bell, n. sp.
Plate 31, figures 10-14

Outline subcircular or transversely ovate; ventral valve conical and of average height for the genus; dorsal valve nearly flat; fila faint and indefinite toward apex, stronger toward margin, blending laterally and longitudinally with adjoining fila; shell calcareo-corneous, laminated, thinner than in *P. trapeza*.

Syntypes, Mont. T1187a-c.

Horizon and locality.—Middle Cambrian. Pentagon shale: 6-2, Pentagon Mt.; 26-4, Lick Creek. Meagher limestone (*Bathyriscus* zone): 45-3, 45-3a, M4-4, M4-4a, Nixon Gulch.

Distinguishing characters.—*Prototreta subcircularis* is characterized by its transversely subcircular outline, rectimarginate or very faintly sulcate anterior commissure, strongly procline ventral interarea, narrow dorsal

propareas, and nearly horizontal septal plate.

Discussion.—*Prototreta subcircularis* occurs in association with *P. trapeza* at two localities; although relatively rare at these places, it is abundant at Pentagon Mountain, where *P. trapeza* is absent. There appear to be no intermediate forms between the adult individuals of the two species, although in young specimens the dorsal valves are very similar.

PROTOTRETA TRAPEZA Bell
Plate 31, figures 34–48;
text figures 5–7

Prototreta trapeza BELL, 1938, Mich. Acad. Sci.,
Papers, vol. 23, p. 405, pl. 1, figs. 1–6.

Outline subtrapezoidal; ventral valve conical and of average height for the genus; dorsal valve moderately convex and sulcate; surface finely and closely filate, the fila blending laterally and longitudinally with adjoining fila; shell calcareoconeous, laminated.

Ventral valve: Posterior margin strongly indented at base of intertrough, anterior margin gently emarginate, posterolateral margins more sharply rounded than anterolateral margins; greatest width at point about one-third length from anterior margin; profile subtriangular; pseudointerarea catacline, distinctly concave; anterior slope more or less strongly convex; intertrough wider and deeper at commissure than at foramen, and characterized by medial well-defined, more or less depressed and flattened triangular granular area; foramen circular, about 0.03 mm. in diameter, situated slightly posterior to apex; fila flexed apically and enlarged by fusion along margins of posterior granular groove. Narrow internal ridge (pl. 31, figs. 39–40), with greatest height and breadth in middle third, extends from apex to center of posterior margin, where a slight projection fits into apical groove of dorsal valve; near its center, ridge bears a deep pit (pl. 31, fig. 38), evidently the internal opening of pedicle tube, which slants ventrally to external foramen (text fig. 6); crest of ridge traversed from pedicle opening to cardinal margin by shallow groove (pl. 31, figs. 39–40); small pit on either side of ridge and slightly dorsal to pedicle opening, probably

seat of muscle attachment (pl. 31, fig. 38); two narrow, slightly diverging ribs extend anteriorly from pedicle opening, and disappear about halfway along anterior slope; strong groove (pallial sinus) borders each rib laterally and extends anteriorly from cardinal muscular pit to point near anterior margin of valve (pl. 31, figs. 39, 41). Inner ends of shell laminae in apical half of valve project inward, forming an incomplete "cone-in-cone" structure (pl. 31, fig. 41; text fig. 7); encircling shelf near apex partly separates a small chamber from main part of valve (pl. 31, fig. 39).

Dorsal valve: Posterolateral margins less strongly rounded than either anterolateral or posterior margins; posterior margin slightly depressed at midpoint; apex marginal, with minute longitudinal groove or pit at summit, and projecting slightly beyond margin of ventral valve; umbo swollen, sharply raised above surfaces lateral to it; posterior part of valve flat, becoming increasingly convex anteriorly; anterior margin straight or gently emarginate, broadly and strongly sulcate; width of sulcus at margin one-third that of shell, becoming narrow and shallow posteriorly, and disappearing before reaching apex; fila bent toward apex in bottom of sulcus, broken, and crinkled into a faint and imperfect criss-cross pattern. Propareas flat, about 45° anacline, raised above interior surface of valve on strong thickening of posterolateral margins, anterior edges project as a shelf; apical groove wide, shallow, traversed medially by a low, narrow ridge; sides of apical groove diverge anteriorly from apex at 90°; median septum (pl. 31, figs. 45–48) stout, expanding laterally in central third of valve into a broad, strong plate, which slopes ventrally beyond plane of commissure; plate apparently composed of five ribs, any or all of which may divide near anterior margin of plate and project as short, delicate fingerlike processes; two pairs of muscle scars positively identified (pl. 31, fig. 45); larger pair on posterior floor of valve, elongated anterolaterally almost in line with margins of apical groove; smaller pair at inner posterior margins of primary scars, adjoining posterior end of septum; third pair tentatively identified adjoining septum near its middle (pl. 31, fig. 45).

	Dimensions (mm.)				
	Length	Width	Height	L/W	H/W
Ventral valve:					
Mich. 20819a.....	2.5	2.9	1.8	0.86	0.62
Dorsal valves:					
Mont. 1535.....	2.7	3.1		0.87	
Mont. T1186b.....	3.2	3.6		0.89	

Holotype, Mont. 1535; paratypes, Mont. T1186a-c; Mich. 20819a-h; figured specimen, Mont. T1191a.

Horizon and locality.—Middle Cambrian. Meagher limestone (*Bathyriscus* zone): 45-3, 45-3a, M4-4, M4-4a, U.S.N.M. loc. 19z, Nixon Gulch; U.S.N.M. loc. 4o, head of Jackson Creek, Teton Mountains, Wyoming. Lower Meagher limestone: 47-3 loose, Beaver Creek. Pentagon shale: 26-4, 26-top (?), Lick Creek.

Distinguishing characters.—*Prototreta trapeza* is characterized by its subtrapezoidal outline, strong dorsal sulcus, catacline ventral pseudointerarea, and very sturdy dorsal septum.

Discussion.—No muscular impressions, other than the so-called cardinal muscular pits were observed in the ventral valve. The convexity of the dorsal valve apparently increases progressively with age. Considerable minor variation in the form of the dorsal septum occurs among associated individuals. The larger pair of muscular scars is visible in almost all dorsal valves, but the smaller pair was seen only in quite mature individuals. A few valves bore roughened callosities on the floor of the valve adjoining the septum opposite its point of lateral expansion; the callosities may represent points of muscular insertion. No evidence of pallial trunks has been observed in the dorsal valve.

Prototreta trapeza has furnished most of the information used in preparing the generic diagnosis. The reason for this is that the shells occur in a soft shale and can be readily cleaned with a needle to expose the important internal structures.

This species has been found in place at only two localities in Montana, where it occurs in similar calcareous shales. In the Teton Mountains of Wyoming it is present in a similar shale. These occurrences suggest that *P. trapeza* is limited to a distinct facies. A single dorsal valve showing the interior, and an associated fragment of a dorsal septum (pl. 31, figs. 36, 44) occur on a piece of

limestone collected from talus at Beaver Creek. These specimens, which are referred to *P. trapeza*, are not quite typical of the species.

Genus HOMOTRETA Bell, n. gen.

(Gr. *ὁμός*, similar; *τρήτα*, bored through)

Shell minute, calcareoconeous, laminated; outline subcircular or transversely subelliptical. Ventral valve like that of *Prototreta*, except that internal "cone-in-cone" structure is not so strongly developed. Dorsal valve like that of *Prototreta*, except that the median septum is high and blade-like, without lateral expansion.

Genotype, *Homotreta interrupta* Bell, n. sp.

Distinguishing characters.—*Homotreta* is characterized by a conical ventral valve with foramen posterior to apex, and internal "cone-in-cone" structure; dorsal valve with flattened propareas bounding a triangular muscular (?) pit, and a high bladelike median septum.

Discussion.—*Homotreta* apparently differs from *Prototreta* only in having a keellike median septum, the crest sloping gently posteriorly and anteriorly from its highest point. Only one species is known from Montana (*H. interrupta*). It appears that *Acrotreta marjumensis* Walcott = *Acrotreta ophiirensis descendens* Walcott belongs to this genus. Probably other species from the Cordilleran province, now assigned to *Acrotreta*, will prove to be congeneric with *Homotreta interrupta* when their internal morphology is made known.

Homotreta differs from *Pegmatreta*, with which it is associated in the "Pagoda" limestone on Lick Creek (localities 26-2, 26-3), in possessing "cone-in-cone" structure of the ventral valve, distinct dorsal propareas and high dorsal septum, and in lacking an internally thickened ventral apex.

HOMOTRETA INTERRUPTA Bell, n. sp.

Plate 30, figures 19-26; text figures 1-4

Outline subcircular or transversely sub-

elliptical; ventral valve conical, dorsal valve slightly convex; fila strongly defined, regularly spaced, slightly crenulated and irregularly segmented on marginal third of valve; distance between crests of ridges about 0.03 mm. on a shell 4 mm. in width; average length of segments about 0.1 mm.; gaps between segments of same ridge about 0.03 mm.; shell calcareocorneous, laminated.

Ventral valve: Posterior margin flattened for a distance that may equal half width of valve, and slightly incurved at base of intertrough; profile triangular; pseudointerarea 20°–25° procline, and straight from apex to margin; anterior slope about twice length of posterior slope and slightly convex, except immediately anterior to apex, where it becomes concave; intertrough wider and deeper at commissure than at apex, and characterized by medial, more or less depressed and flattened granular area; foramen circular, 0.03 mm. in diameter, situated slightly posterior to apex. Interior like that of *Prototreta flabellata*, so far as can be determined.

Dorsal valve: Profile slightly convex, greatest convexity being near middle of valve; posterior margin slightly depressed at midpoint; apex minute, marginal, knob-like, with pit or longitudinal groove at summit; anterior margin gently sulcate; sulcus becoming narrow and shallow posteriorly, disappearing on elevated umbo; fila bent abruptly posteriorly along median line of sulcus, where they break and develop a distinct criss-cross pattern (pl. 30, fig. 22). Pseudointerarea (muscular pit and propareas) like that in *Prototreta subcircularis*; median septum a narrow bladlike structure, the crest of which rises slowly to its highest point in anterior third of valve, and thence slopes abruptly to the anterior margin (text fig. 2).

proved impossible to excavate the interior of the ventral valve, all information has been obtained from serial sections and one imperfect internal mold. So far as can be ascertained, the ventral internal structure is quite similar to that of *Prototreta trapeza*, the shell being somewhat thinner. The cardinal muscular pits, the two diverging pallial trunks, and the callosity behind the intertrough have been observed. Cross-sections clearly show the internal ends of the shell laminae extending into the apical cavity (text figs. 3–4).

Homotreta interrupta is a homoeomorph of *Prototreta flabellata*, differing from it only in internal characters. This relationship has been discussed in the section on Homoeomorphy.

Genus PEGMATRETA Bell, n. gen.

(Gr. $\pi\eta\gamma\mu\alpha$, thickened;
 $\tau\rho\eta\tau\alpha$, bored through)

Outline subcircular or transversely subelliptical; ventral valve obliquely conical, or strongly convex with incurved apex; dorsal valve slightly or moderately convex; surface finely filate; shell calcareocorneous, laminated.

Ventral valve: Intertrough moderately developed; foramen circular, posterior to apex. Apex strongly thickened internally by a subconical callosity with deeply excavated posterior slope, forming a deep pit, into which the pedicle tube opens; shell laminae do not project into the interior.

Dorsal valve: Umbo swollen; beak strongly incurved; apex without pit or groove at summit. Triangular muscular pit present at apex; posterolateral margins of valve hardly thickened, propareas barely perceptible; septum a long, low, narrow, rounded ridge.

Genotype, *Pegmatreta perplexa* Bell, n. sp.
Distinguishing characters.—*Pegmatreta* is

	Dimensions (mm.)				
	Length	Width	Height	L/W	H/W
Ventral valve:					
Mont. T1194b.....	2.9	3.7	1.4	0.78	0.38
Dorsal valve:					
Mont. T1194c.....	2.7	2.9		0.93	

Syntypes, Mont. T1194a–h.

Horizon and locality.—Middle Cambrian. "Pagoda" limestone: 26-2, 26-3, Lick Creek; 28-1, Rock-Baldy Bear Creek ridge.

Discussion.—As, unfortunately, it has

characterized by the strong internal thickening of the ventral apex, pedicle foramen posterior to apex, obsolete dorsal propareas, and low median ridge in the dorsal valve.

Discussion.—Several described species,

now assigned to *Acrotreta*, may belong to *Pegmatreta*, but an investigation of them is beyond the scope of this paper. It should be pointed out that *Acrotreta ophirensis* Walcott and *A. idahoensis* Walcott have strongly thickened ventral apices, and foramina posterior to the apex. Both species

swollen; beak incurved; apex without pit or groove at summit; anterior margin usually faintly sulcate; sulcus most distinct on anterior slope of umbo. Propareas indistinct, bordering a wide shallow pit, probably for muscular attachment; septum long, low, narrow.

	Dimensions (mm.)				
	Length	Width	Height	L/W	H/W
Ventral valve:					
Mich. 20810a.....	2.1	2.55	0.5?	0.82	0.2
Dorsal valve:					
Mich. 20810b.....	1.75	2.00		0.87	

have much thicker shells than have *Pegmatreta rotunda* and *P. perplexa*, which may account for the apparent internal differences in the dorsal valves.

Pegmatreta perplexa and *P. rotunda*, described in this paper, are strikingly different in the form of their ventral valves, but are placed in the same genus because of internal similarities. Possibly the characters regarded here as generic may prove to be of family rank, but further investigation is necessary to answer this question.

PEGMATRETA PERPLEXA Bell, n. sp.
Plate 30, figures 11-14;
text figure 11

Outline subcircular to transversely subelliptical; ventral valve obliquely subconical, dorsal valve slightly convex; fila distinct, threadlike, often segmented. Shell calcareo-coneous, laminated.

Ventral valve: Posterior margin slightly indented at base of intertrough; profile obtusely subtriangular; pseudointerarea about 45° procline and straight from apex to margin, anterior slope slightly and regularly concave; intertrough shallow, characterized by flattened and granular center; foramen circular, 0.03 mm. in diameter, opening backward through slight subquadrate callosity on posterior side of truncated apex. Apex strongly thickened internally into a subconical callosity; margin of callosity extended a short distance anteriorly as a ridge; posterior slope of callosity excavated by a deep pit, into floor of which opens the pedicle foramen; pair of depressions on anterolateral slopes of callosity may be muscular scars.

Dorsal valve: Profile gently convex; umbo

Syntypes, Mich. 20810a-c.
Horizon and locality.—Middle Cambrian. Meagher limestone (*Bathyriscus* zone): 45-3, 45-3a, M4-4, M4-4a, Nixon Gulch. Lower Meagher limestone: 47-3, Beaver Creek. "Pagoda" limestone: 26-2, 26-3, Lick Creek. Pentagon shale: 6-2, Pentagon Mountain; 26-4, Lick Creek.

Distinguishing characters.—*Pegmatreta perplexa* is characterized by its obtusely conical ventral valve with a circular foramen opening from a subquadrate callosity posterior to apex.

Discussion.—The presence of *Pegmatreta perplexa* in both the "Pagoda" limestone and Pentagon shale is unexpected; so far as can be determined, the "Pagoda" specimens differ from those in the Pentagon only in being uniformly somewhat larger and in having a slightly more rounded ventral apex. Inasmuch as the preservation of the specimens in the fine-grained calcareous shales of these formations is not sufficiently good to ascertain whether slight specific differences exist, it seems best at present to assign the "Pagoda" and Pentagon forms to the same species.

Pegmatreta perplexa is readily distinguished from all other species in Montana, as well as from all described species now assigned to *Acrotreta*, by its very obtusely conical and low ventral valve, with a circular foramen posterior to the apex.

PEGMATRETA ROTUNDA Bell, n. sp.
Plate 30, figures 27-31;
text figure 17

Outline subcircular to transversely subelliptical; ventral valve strongly convex, with beak incurved over posterior margin; dorsal

valve slightly convex; surface fila fine, continuous, tending to crinkle near anterior margin of shell; shell calcareoconeous, laminated.

Ventral valve: Posterior margin slightly indented at base of intertrough; profile strongly convex, highest point being in posterior third of valve; pseudointerarea catacline; intertrough present, narrow; beak incurved and crushed in all available specimens; foramen unknown, but probably posterior to apex. Interior like that of *P. perplexa*, so far as observed, with subconical callosity projecting inward and bounding a deep pit posterior to it; shell laminae do not project into interior of valve (text fig. 17).

Dorsal valve: Profile moderately convex, with swollen umbo and incurved beak; apex without pit or groove at summit. Interior like that of *P. perplexa*; propleas obsolete; shallow triangular depression at apex, probably for muscular attachment; septum long, low, slightly wider anteriorly.

which event the two species may prove to be congeneric.

P. rotunda is known from only one locality, and all the specimens available for study are more or less crushed and broken. The matrix, a fine-grained, hard, shaly limestone, is difficult to remove with a needle, and consequently preparation by this method yielded meager results. The information regarding the thickened ventral apex came from thin sections (text fig. 17).

Genus CERATRETA Bell, n. gen.

(Gr. *κέρας*, horn; *τρήτα*, bored through)

The genus *Ceratreta* is proposed to include a single species of Upper Cambrian acrotretids, characterized by a bluntly subconical ventral valve with deep intertrough and foramen posterior to apex, and a dorsal valve with an internal median septum, which is projected into a stout vertical hornlike process near its anterior end. The shell is calcareoconeous and laminated.

Dimensions (mm.)					
	Length	Width	Height	L/W	H/W
Ventral valve:					
Mont. T1195a.....	4.0?	4.4?	0.83	0.91	0.19
Dorsal valves:					
Mont. T1195b.....	3.2	3.3?		0.97	
Mont. T1195c.....	4.2	4.5		0.93	

Syntypes, Mont. T1195a-e.

Horizon and locality.—Middle Cambrian. "Pagoda" limestone: 26-2, 26 3, Lick Creek.

Distinguishing characters.—*Pegmatreta rotunda* is characterized by its strongly convex ventral valve, with apex incurved over catacline pseudointerarea.

Discussion.—*Pegmatreta rotunda* is readily distinguished from any other species in Montana by the form of its ventral valve, but it is strikingly similar to *Acrotreta ophirensis* Walcott from the Middle Cambrian of the Oquirrh (Ophir formation) and House (Marjum formation) Ranges, Utah. The latter species, in addition to having a much more convex dorsal valve, differs from *Pegmatreta rotunda* in possessing structures and markings, in addition to the median septum, on the floor of the dorsal valve. These structures and markings may be present only because *Acrotreta ophirensis* has a much thicker shell than *Pegmatreta rotunda*, in

Genotype, *Ceratreta hebes* Bell, n. sp.

Discussion.—The single species of this genus is known from only three localities, and the specimens are neither abundant nor well preserved. In the writer's opinion the hornlike projection of the dorsal septum is the most striking generic character. This type of septum has not previously been described, but is present in *Acrotreta microscopica* (Shumard). (See discussion of "*Acrotreta*" *tetonensis*.)

CERATRETA HEBES Bell, n. sp.

Plate 29, figures 10-17

Outline subcircular or transversely subelliptical; ventral valve bluntly conical; dorsal valve moderately convex; surface distinctly and finely filate; shell calcareoconeous, laminated.

Ventral valve: Profile subsemielliptical, highest point being anterior to apex; pseudointerarea about 30° procline and straight from apex to margin; anterior slope strongly

convex; intertrough present on apical half of posterior slope, narrow, deep; marginal half of posterior slope slightly flattened; foramen circular, minute, situated at upper end of intertrough just below incurved apex; apex rounded, somewhat knoblike. Interior with high median ridge on posterior slope; pedicle tube slants dorsally from foramen through ridge toward interior of valve (pl. 29, fig. 16).

Dorsal valve: Profile moderately convex, highest point at middle of valve; beak strongly incurved over posterior margin; apex blunt, without pit or groove at summit. Interior with subtriangular concave shelf at apex, presumably for muscular attachment, somewhat excavated below on either side of median septum; septum stout, rounded in cross section, originating below level of apical shelf, and projecting into a high hornlike process in anterior third of valve; slight depression present on crest of septum at its posterior end.

Dimensions (mm.) of Ceratreta hebes

	Length	Width	Height	L/W	H/W
Ventral valve:					
Mont. T1197b.....	1.25?	1.75?	0.88?	0.71	0.5
Dorsal valve:					
Mont. T1197a.....	1.5?	1.9?		0.79	

Syntypes, Mont. T1197a-f.

Horizon and locality.—Upper Cambrian. Dry Creek shale: 46-3, Nixon Gulch. Snowy range formation: M1-4, Beartooth Butte; M2-1, Cooke.

Distinguishing characters.—*Ceratreta hebes* is characterized by its bluntly conical ventral valve, with deep intertrough and foramen posterior to apex, concave shelf at apex of dorsal valve, and median dorsal septum projected into a high hornlike process.

Discussion.—*Ceratreta hebes* is distinguished from all other brachiopods known to the writer by the form of its ventral valve.

The ventral interior of this species is not well known, but a fractured valve (pl. 29, fig. 16) shows clearly the nearly vertical pedicle tube contained within the high ridge on the inner side of the posterior slope. (See "*Acrotreta*" *tetonensis* for a discussion of the

apparent relationship of *Ceratreta hebes* to *Acrotreta microscopica*.)

"ACROTRETA" *TETONENSIS* Walcott

Plate 31, figures 1-9

Acrotreta microscopica tetonensis WALCOTT, 1902, U. S. Nat. Mus., Proc., vol. 25, p. 590; 1912, U. S. Geol. Survey, Mon. 51, p. 694, pl. 67, figs. 3, 3a-d.

Outline subcircular; ventral valve obliquely and sharply subconical; dorsal valve slightly convex; fila fine, sharp, continuous; shell calcareoconeous, laminated.

Ventral valve: Posterior margin nearly straight; profile obliquely subtrigonal; pseudointerarea slightly curved, about 80° apascline; anterior slope moderately convex; apex sharply pointed, perforated by a circular foramen, and extending beyond posterior margin; pseudointerarea distinctly flattened to slightly concave, crossed smoothly by fila, which flex gently toward apex; intertrough absent. Interior with strong cardinal

muscular pits near posterolateral margins of valve; pedicle tube opens internally into a central chamber, which is separated from two lateral chambers of the valve by a pair of strong septa; central chamber occupies probably apical third to half of valve; septa fuse near middle of anterior slope and form a broad low elevation (pl. 31, fig. 3).

Dorsal valve: Profile moderately convex; central posterior margin slightly depressed; apex knoblike, elevated above surface of valve lateral to it, and carrying median groove at summit. Interior with moderately developed propareas bounding central subtriangular depression; broad, low callosity anterior to apical depression continued (?) anteriorly as a low narrow septum; broad cardinal muscular scars present on posterolateral margins of valve floor, adjoining inner margins of propareas.

Dimensions (mm.) of "Acrotreta" tetonensis

	Length	Width	Height	L/W	H/W
Ventral valve:					
Mont. T1199b.....	1.25?	1.4?	0.75?	0.89	0.54
Dorsal valve:					
Mont. T1199e.....	1.5?	1.5?		1.00	

Hypotypes, Mont. T1199a-g.

Horizon and locality.—Upper Cambrian. Dry Creek shale: 44-2, Crowfoot Ridge; 46-3, Nixon Gulch; U.S.N.M. localities 4e, head of Jackson Creek, Teton Mountains, Wyoming; 302w, Madison Mt. Snowy Range formation: M1-4, Beartooth Butte.

Discussion.—Unfortunately, only a few fragmental dorsal valves are present in the writer's collections of "*A.*" *tetonensis*, and they yield discouragingly little information. The dorsal valves among the types of "*A.*" *tetonensis* are all exteriors, and there is no surplus material that can be prepared to reveal the interior. "*A.*" *tetonensis* and *Acrotreta microscopica* (Shumard) are very similar, apparently differing only in the form of the ventral valve. Investigation of a dorsal valve of *A. microscopica* from U.S.N.M. loc. 67, Burnet County, Texas, revealed an internal septum projected into a high horn-like elevation, like that in *Ceratreta hebes*. Unfortunately, the problem could not be investigated further. If all the dorsal valves have been correctly assigned, there is a close, at least family, relationship between *Ceratreta hebes* on the one hand, and "*Acrotreta*" *tetonensis* and *Acrotreta microscopica* on the other.

Genus LINNARSSONELLA

Walcott, 1902

LINNARSSONELLA ELONGATA Bell, n. sp.

Plate 31, figures 15-19;
text figures 8-10

Outline elongate subtrigonal, greatest width anterior to middle; anterior margin broadly rounded, posterior margin more sharply rounded; profile unequally biconvex, convexity of ventral valve being the greater; surface very glossy, with subdued growth lines; shell calcareoconeous, laminated, greatly thickened in umbonal region.

Ventral valve: Profile strongly convex, greatest convexity in posterior third of valve; beak bluntly pointed, incurved; pseudointerarea about 60° apsacline, not flattened, characterized by increased rugosity and very close grouping of growth ridges; foramen minute, circular, situated immediately posterior to apex. Middle of posterior commissure slightly convex dorsally, the projection fitting into apical depression of dorsal valve; posterolateral margins narrow

and slightly projected dorsally as "teeth," which fit into deep furrows in dorsal valve; foramen opens internally into narrow, deep furrow, which widens slightly anteriorly and disappears about one-third length of valve from apex; cardinal muscular pits deep, situated in posterolateral slopes about opposite "teeth"; pallial trunks straight, shallow, divergent, originating adjacent to median furrow near apex.

Dorsal valve: Shorter and less acuminate posteriorly than ventral valve; profile moderately convex, greatest convexity in posterior third of valve; beak incurved; apex marginal, formed by a pair of minute projections. Posterior portion of valve strongly thickened internally into a broad and long platform with concave upper surface, presumably for muscular insertion and reception of projecting margin of ventral valve; posterolateral margins thickened, bearing deep furrows for reception of "teeth" of ventral valve; short, stout median septum or ridge originates at anterior margin of apical platform and extends to middle of valve; crest of ridge broadened and flattened at its posterior end; pair of deep cardinal muscular pits present, excavated in thickened posterolateral slopes of valve.

Dimensions (mm.)

	Length	Width	L/W
Ventral valve:			
Mich. 20811e.....	2.33	2.0	1.16
Dorsal valve:			
Mich. 20811d.....	2.17	2.0	1.08

Syntypes, Mich. 20811a-e.

Horizon and locality.—Upper Cambrian. Dry Creek shale: 44-2, Crowfoot Ridge. Snowy Range formation: M1-4, Beartooth Butte.

Distinguishing characters.—*Linnarssonella elongata* is characterized by its elongate subtrigonal outline, strong biconvexity, bluntly rounded ventral apex, and slightly apsacline, unflattened ventral pseudointerarea.

Discussion.—*Linnarssonella elongata* differs from *L. girtyi* Walcott, the only described species of *Linnarssonella* of which the type or topotype specimens are well enough preserved for comparison, in having an elongate subtrigonal outline, a more bluntly rounded ventral apex, and an unflattened ventral pseudointerarea.

Genus *NISUSIA* Walcott, 1905

The studies by Schuchert and Cooper (1932, p. 44) and Cooper (1936, p. 212) have established the generic characters of *Nisusia* quite completely. No additional information concerning the internal structure of the genus resulted from the present study.

Among the species of *Nisusia* represented in the United States National Museum by ventral valves sufficiently well preserved to show the original convexity, *N. lowi* (Walcott) and *N. spencei*⁷ (Walcott) are unique in that the highest part of the valve is toward the middle, the apex being incurved over a moderately apsacline interarea. In contrast, *N. alberta* (Walcott), *N. amii* (Walcott), *N. burgessensis* Walcott, *N. borealis* Cooper, *N. erecta* (Walcott), *N. festinata* (Billings) (genotype), and *N. utahensis* (Walcott) are characterized by a ventral valve in which the apex is the highest point, the interarea being strongly apsacline to catacline. *Nisusia deissi* and *N. montanaensis* described in this paper belong to the former group, whereas *N. lickensis* and *N. sp. 1* belong to the latter. None of the four species belonging to the evenly convex group possess spinose costellae, but many, if not most of the uptilted-apex type do possess spines. It may be that these differences are of generic rank, but more information is needed before the question can be decided.

⁷ Resser's (1939a, p. 6) assignment of *Nisusia spencei* (Walcott) and *N. rara* Walcott to the genus *Wimanella* is without foundation.

NISUSIA DEISSI Bell, n. sp.

Plate 32, figures 1-6

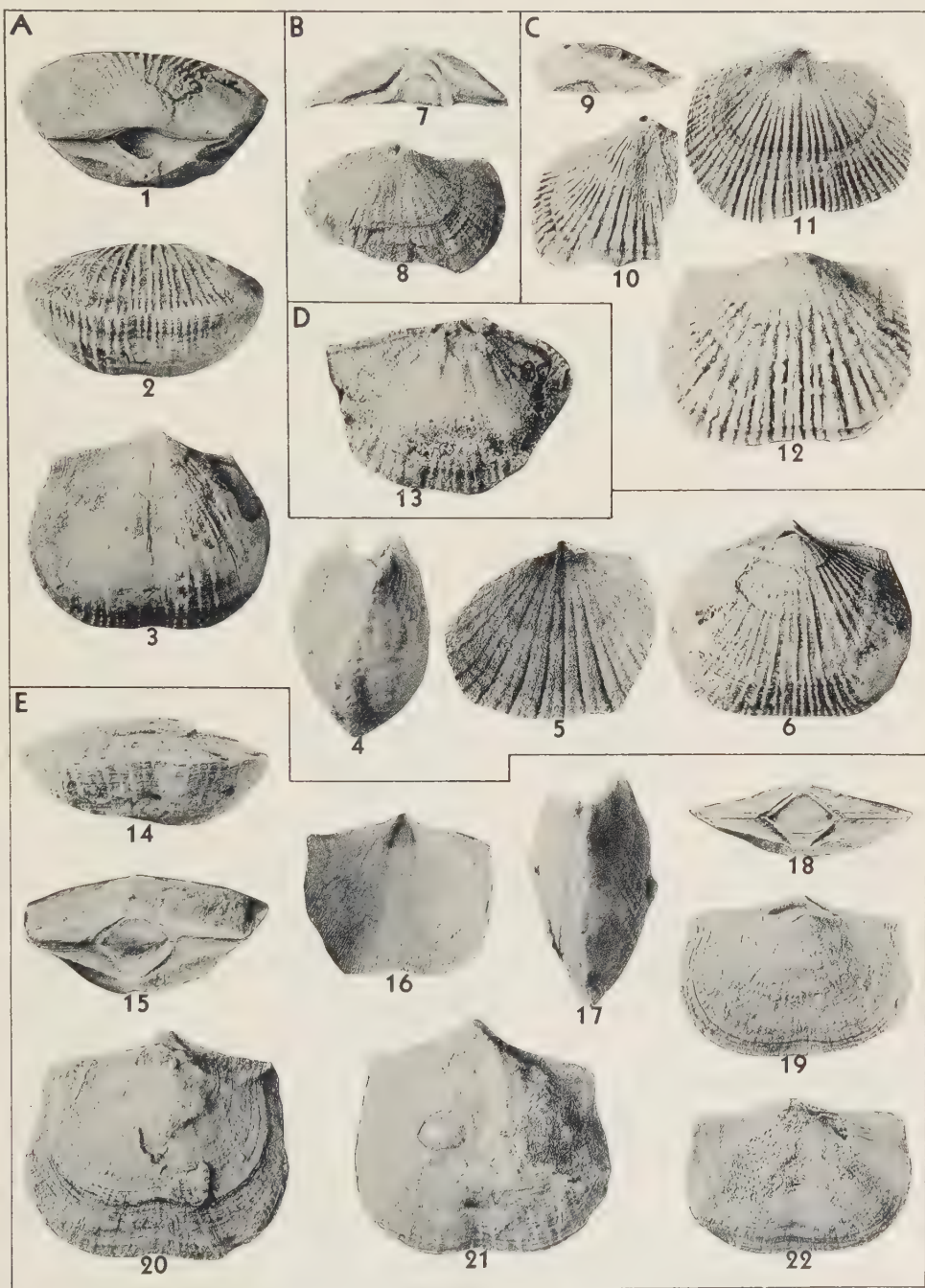
Nisusia sp. COOPER, 1936, Jour. Paleontology, vol. 10, no. 3, pl. 26, figs. 27, 29.

Outline transversely rounded subrectangular; lateral margins smoothly and gently convex outward; hinge less than width of valve at middle; cardinal extremities obtusely angular, slightly mucronate in immature individuals; anterior commissure emarginate; sulcus present in both valves, somewhat narrower and deeper in ventral valve; profile strongly and evenly biconvex, the convexity of the dorsal valve being slightly the greater; both beaks incurved, the dorsal more so than the ventral; ventral interarea longer than dorsal; surface evenly paucicostellate, costellae strong, rounded, beaded near margin by junction with rugose growth lamellae; intercostellate areas flat, twice width of costellae, crossed only by fila and strong growth ridges.

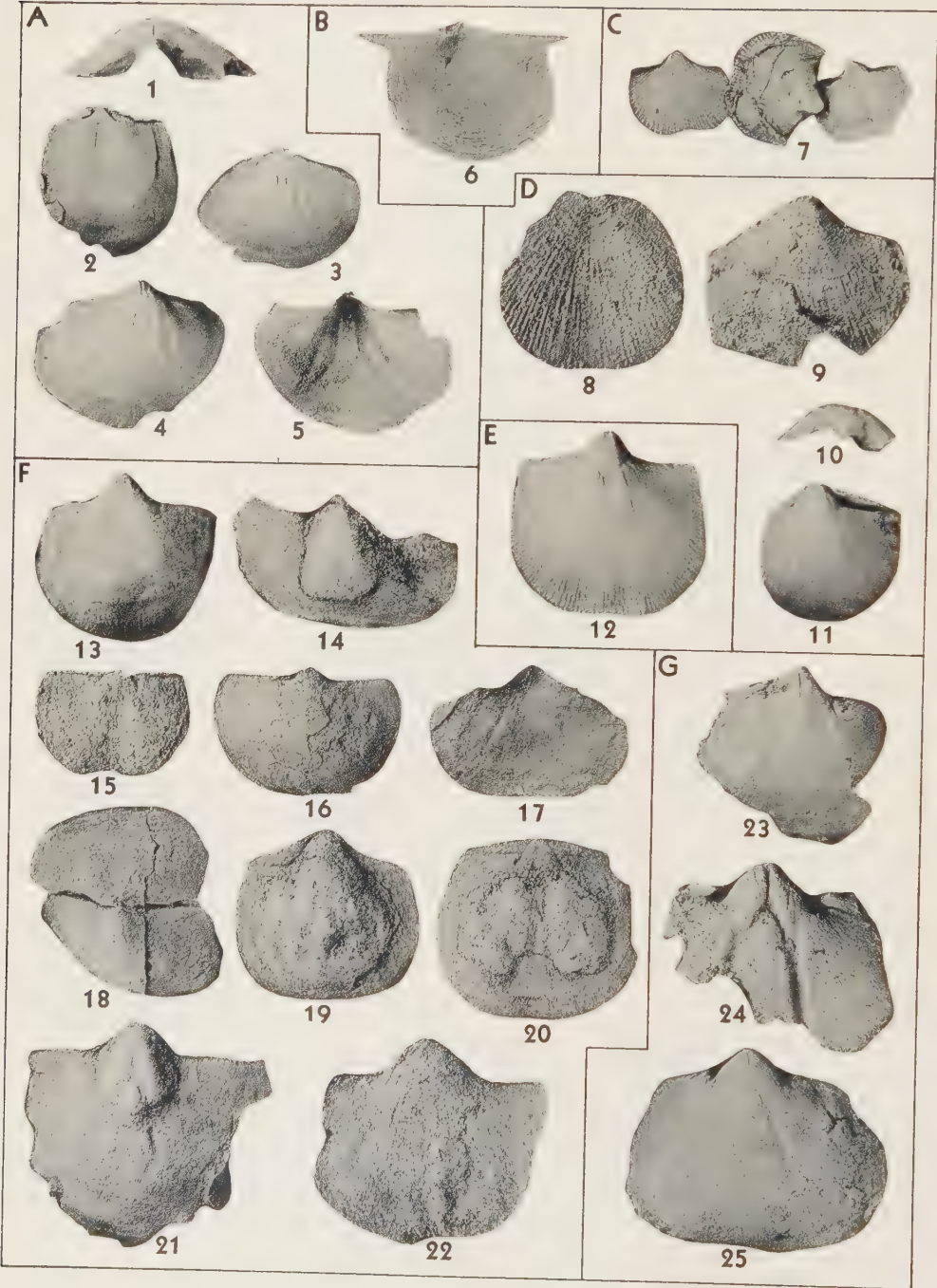
Ventral valve: Posterior margins slightly concave; apex pointed, apical angle about 140°; sulcus a gentle flexure of shell, faint at apex, deeper and wider at margin; convexity greatest slightly anterior to middle of shell; interarea concave, about 30° apsacline; delthyrium wide, apical third covered by short, thick, very convex deltidium; delthyrial angle about 90°; apical foramen small, circular, evidently shared both by deltidium and apex of valve. Interior paucicostellate, without muscular and pallial markings in all specimens observed.

EXPLANATION OF PLATE 32

- FIGS. 1-6—*Nisusia deissi* Bell, n. sp. 1-4, 6, Holotype; posterior, anterior ventral, lateral, and dorsal views of a complete specimen, Mich. 20803a, ×2, loc. M3-1. 5, Paratype; interior of incomplete ventral valve, showing costellation, Mich. 20803b, ×3, loc. M3-1. Middle Cambrian: Meagher limestone. (p. 236)
- 7-8—*Nisusia* sp. 1. Figured specimen; posterior and surface views of incomplete ventral valve, Mont. T1176a, ×3, loc. 20-2. Middle Cambrian: Damnation limestone. (p. 239)
- 9-12—*Nisusia lickensis* Bell, n. sp. 9, 10, Syntype; posterior and surface views of incomplete ventral valve, showing short adductor track and linear diductor tracks, Mont. T1178c, ×3, loc. 26-top. 12, Syntype; exterior of dorsal valve, showing stout nodes or spine bases on costellae Mont. T1178b, ×3, loc. 26-loose. Middle Cambrian: Pentagon shale. (p. 238)
- 13—*Nisusia*, sp. 2. Figured specimen; badly weathered internal mold showing suggestion of notothyrial platform, Mont. T1179a, ×2, loc. 20-2. Middle Cambrian: Damnation limestone. (p. 239)
- 14-22—*Nisusia montanaensis* Bell, n. sp. 14, 15, 17, 20, 21, Holotype; anterior, posterior, lateral, dorsal, and ventral views of a complete mature specimen, Mich. 20804a, ×2, loc. M3-1. 16, Paratype; interior of incomplete ventral valve, showing absence of costellae and muscular impressions, Mich. 20804c, ×2, loc. M3-1. 18, 19, 22, Paratype; posterior, dorsal, and ventral views of a complete immature specimen, Mich. 20804b, ×2, loc. M3-1. Middle Cambrian: Meagher limestone (p. 236)



Bell, Cambrian Brachiopoda



Bell, Cambrian Brachiopoda

Dorsal valve: Outline transversely subquadrate, or subelliptical except for obtusely angular or slightly mucronate cardinal extremities; hinge considerably less than width of valve at middle; posterior margins concave; apex bluntly rounded, apical angle about 160°; sulcus broad, shallow, not apparent in posterior third of valve; interarea short, flat, about 60° anacline; notothyrium wide, open so far as observed; notothyrial angle about 100°. Interior paucicostellate,

without muscular and pallial markings in all specimens observed.

Dimensions (mm.)

	Length	Width	Hinge width	L/W
Ventral valve:				
Mich. 20803a....	14.5	17.0	13.5	0.85
Dorsal valve:				
Mich. 20803a....	13.3	17.0	13.5	0.78

Holotype, Mich. 20803a; paratype, Mich. 20803b.

EXPLANATION OF PLATE 33

- FIGS. 1-5—*Wimanella rossensis* Resser. 1, 4, Hypotype; posterior and surface views of ventral internal mold, showing broad compound pallial trunks, restricted adductor impression, apical septum, and inflected posterior margin of delthyrial cavity, U.S.N.M. 97072, $\times 3$, loc. 63m'. 5, Hypotype; clay squeeze from same mold, U.S.N.M. 97072, $\times 3$, loc. 63m'. 2, Syntype (Walcott, 1917a, pl. 4, fig. 8a, as ventral valve); surface view of dorsal internal mold, showing impressions of brachiophores, U.S.N.M. 63717, $\times 2$, loc. 63m'. 3, Syntype (Walcott, 1917a, pl. 4, fig. 8); surface view of ventral internal mold, U.S.N.M. 63716, $\times 2$, loc. 63m'. Middle Cambrian: Ross Lake shale member of Cathedral dolomite, south slope of Mt. Bosworth, British Columbia. (p. 241)
- 6—*Wimanella auralis* Bell, n. sp. Holotype; impression of exterior of ventral valve, Mont. T1192a, $\times 3$, loc. 40-2. Middle Cambrian: Wolsey shale. (p. 241)
- 7—*Diraphora bellicostata* (Walcott). Hypotypes; three ventral valves, including one exterior and two partial internal molds. The center valve shows clearly the strong pallial trunks and narrow diductor tracks apparently continuous with them, U.S.N.M. 97077, $\times 1.5$, loc. 35k. Middle Cambrian: Burgess shale, above Field, British Columbia. (p. 243)
- 8-11—*Diraphora striata* (Walcott), 8, Paratype (Mon. 51, pl. 86, fig. 4c); exterior of incomplete and poorly preserved dorsal valve, presumably belonging to this species, U.S.N.M. 52279d, $\times 3$, loc. 149a. 9, Holotype (Mon. 51, pl. 86, fig. 4); exterior of incomplete ventral valve, U.S.N.M. 52279a, $\times 3$, loc. 149a. 10, 11, Hypotype; posterior and surface views of ventral internal mold, showing compound pallial trunks and narrow diductor tracks apparently continuous with them, U.S.N.M. 52279e, $\times 2$, loc. 149a. Middle Cambrian: Meagher limestone. (p. 243)
- 12—*Diraphora?* sp. Figured specimen; surface view of ventral internal mold. Mont. T1183a, $\times 3$, loc. 47-2. Middle Cambrian: Meagher limestone. (p. 244)
- 13-22—*Wimanella simplex* Walcott. 13, Hypotype; surface view of ventral internal mold, showing widely divergent pallial trunks, and radial striae near anterior margin of mold, Mont. T1184a, $\times 3$, loc. 23-1. 14, Hypotype; internal mold of delthyrial cavity, showing narrow diductor tracks, U.S.N.M. 52277e, $\times 3$, loc. 4w. 15, Hypotype; surface view of dorsal internal mold, U.S.N.M. 97073d, $\times 3$, loc. 4v. 16, Holotype (Mon. 51, pl. 89, fig. 2); exterior of crushed and poorly preserved ventral valve, U.S.N.M. 52278a, $\times 3$, loc. 4v. 17, Hypotype; interior of incomplete ventral valve, showing widely divergent pallial trunks, U.S.N.M. 52278c, $\times 2$, loc. 4v. 18, Paratypes (Mon. 51, pl. 89, fig. 2e); exteriors of associated dorsal and ventral valves, U.S.N.M. 52278b, $\times 3$, loc. 4v. 19, Hypotype; surface view of ventral internal mold, showing procline interarea and deep delthyrial cavity, U.S.N.M. 97073b, $\times 3$, loc. 4v. 20, Hypotype; surface view of dorsal internal mold, showing anacline interarea, broad notothyrial ridge that may be a rudimentary cardinal process, and faint radial striae near anterior margin of mold, U.S.N.M. 97073a, ca. $\times 2$, loc. 4v. 21, Hypotype (Mon. 51, pl. 89, fig. 2d); surface view of ventral internal mold, showing abnormal development of diductor tracks and adductor impression, U.S.N.M. 52277d, $\times 2$, loc. 4w. 22, Hypotype; surface view of ventral internal mold, showing faintly the radial striae in marginal portion of valve, U.S.N.M. 52277f, $\times 3$, loc. 4w. Middle Cambrian: Gordon shale. (p. 242)
- 23-25—*Wimanella highlandensis* (Walcott). 24, Holotype (Mon. 51, pl. 87, fig. 4b); surface view of incomplete ventral internal mold, showing abnormal development of diductor scars and the ridge or septum between them, U.S.N.M. 15355c, $\times 3$, loc. 31a. 23, Paratype (Mon. 51, pl. 87, fig. 4a), and 25, hypotype; surface views of ventral internal molds showing what is thought to be a more normal development of the adductor impression, diductor tracks, apical septum, and pallial trunks, U.S.N.M. 15355b ($\times 2$), 15355e ($\times 1.5$), loc. 31a. Middle Cambrian: probably Comet shale (Deiss, 1938, p. 1160), near Pioche, Lincoln County, Nevada. (p. 241)

Horizon and locality.—Middle Cambrian. Meagher limestone (*Ehmania* zone): M3-1, U.S.N.M. loc. 20k, Pole Creek; 43-3, Crow-foot Ridge; U.S.N.M. 5k (1) (?), head of Sawmill Creek. Limestone in upper Wolsey shale: 31-1 (?), Hoover Creek; 34-5 (?), South Hill; U.S.N.M. loc. 5f (?), head of Sawmill Creek. "Pagoda" limestone: 28-1, Rock-Baldy Bear Creek ridge.

Distinguishing characters.—*Nisusia deissi* is characterized by its strong biconvexity, very short and convex deltidium, small circular apical foramen, and strong rounded costellae with wide flat interspaces. There appears to be no described species of *Nisusia* with which *N. deissi* might be confused.

NISUSIA LICKENSIS Bell, n. sp.

Plate 32, figures 9-12

Outline transversely subrectangular; hinge less than width of valve at middle; cardinal extremities obtusely rounded or angular; anterior commissure emarginate; profile moderately and asymmetrically biconvex, ventral valve being highest at apex; ventral interarea much longer than dorsal; surface coarsely and evenly fascicostellate, the costellae bearing nodes or spine bases; growth lamellae rarely present.

Ventral valve: Posterior margins evenly concave; apex pointed; apical angle about 135°; anterior slope convex marginally and concave near beak, making apex highest point of valve; sulcus narrow, shallow, most prominent in middle portion of valve; interarea strongly apsacline; deltidium convex, covering about half of delthyrium, its lower margin concave; foramen prominent, shared by apex and deltidium. Interior coarsely fascicostellate; adductor track short, broad; diductor scars linear, projecting anteriorly beyond adductors.

Dorsal valve: Posterior margins faintly concave; apex broadly rounded; apical angle about 160°-165°; umbo slightly swollen, posterolateral flanks flattened to concave; sulcus shallow, broad; profile evenly convex, highest near middle. Interior fascicostellate.

Dimensions (mm.)

	Length	Width	Hinge width	L/W
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Dorsal valve:

Mont. T1178b...	8.8	11.8	10.5?	0.74
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Syntypes, Mont. T1178a-c.

Horizon and locality.—Middle Cambrian. Pentagon shale: 26-top, 26-loose, Lick Creek.

Discussion.—*Nisusia lickensis* appears most closely related to *N. alberta* Walcott and *N. borealis* Cooper. It differs from the former in being smaller and considerably less transverse, and in having obtuse or rounded instead of acutely angular cardinal extremities. From the latter it differs in having a more evenly convex and swollen dorsal valve, and in possessing spines which are stouter and relatively farther apart on the costellae.

NISUSIA MONTANAENSIS Bell, n. sp.

Plate 32, figures 14-22

Outline transversely subrectangular in immature individuals, approaching subquadrate in mature shells; lateral margins subparallel; hinge slightly less than width of shell at middle; cardinal extremities mucronate in young specimens, becoming obtusely angular in mature shells; anterior commissure slightly emarginate; sulcus present in both valves, ventral sulcus being the deeper; profile moderately and subequally biconvex, greatest height in posterior third of shell; ventral beak incurved, projecting slightly beyond that of dorsal; ventral interarea slightly longer than dorsal; surface subdued paucicostellate; costellae low, rounded, scarcely affected by numerous fila and growth lamellae.

Ventral valve: Posterior margins straight, becoming concave near beak, which is obtusely pointed; apical angle of a large valve about 135°; interarea concave, about 45° apsacline; delthyrium wide, apical third or less covered by moderately convex deltidium; delthyrial angle about 90°; apical foramen minute, and sealed in most specimens. Interior smooth, so far as known, without pallial and muscular marks.

Dorsal valve: Outline transversely subrectangular to subquadrate; lateral margins subparallel; posterior margins straight; apical angle nearly 180°; interarea flat, strongly ancline; notothyrium wide; notothyrial angle about 100°; small chilidium present. Interior smooth, so far as known, without pallial and muscular marks.

Dimensions (mm.)

	Length	Width	Hinge width	L/W
Ventral valves:				
Mich. 20804a....	16.2	18.1	15.3	0.90
Mich. 20804b....	11.6	16.4	14.5	0.71
Dorsal valves:				
Mich. 20804a....	15.0	18.1	15.3	0.83
Mich. 20804b....	10.6	16.4	14.3	0.65

Holotype, Mich. 20804a; paratypes, Mich. 20804b-c.

Horizon and locality.—Middle Cambrian. Meagher limestone (*Ehmania* zone): M3-1, U.S.N.M. loc. 20k, Pole Creek; U.S.N.M. loc. 159 (?), north of West Gallatin River. "Pagoda" limestone: 28-loose, Rock-Baldy Bear Creek ridge.

Distinguishing characters.—*Nisusia montanaensis* is characterized by its moderate, subequally biconvex profile and subdued paucicostellae. It differs from *N. deissi*, with which it is associated, in being much less convex and in having much weaker costellae.

NISUSIA sp. 1

Plate 32, figures 7, 8

Known only from ventral valves. Outline transversely subrectangular; posterior margins slightly concave; cardinal extremities rounded; hinge less than width of valve at middle; sulcus broad, shallow; interarea long, concave, strongly apsacline; anterior slope convex marginally and concave on beak; apex highest point of valve; delthyrium convex, covering one-third of delthyrium and extending as narrow wings along margins of delthyrium to its base; surface subdued to strongly costellate or fascicostellate, filate, and rarely concentrically lamellose; costellae without spines.

Figured specimen, Mont. T1176a.

Horizon and locality.—Middle Cambrian. Damnation limestone: 20-2, Scapegoat Basin.

Discussion.—Specimens of this species occur at only one locality and are fragmentary and poorly preserved. So far as can be determined, the species is most closely related to *N. lickensis* Bell, n. sp., differing from it in having less coarse costellae, which are without spines.

NISUSIA sp. 2

Plate 32, figure 13

In the Damnation limestone of Scapegoat Basin occur two poor dorsal internal molds

of *Nisusia* characterized by large size, strong convexity, great width relative to length, alate cardinal extremities, and coarse costellae. The molds, although badly weathered, indicate the existence of a low notothyrial platform. The specimens seem to be unique among species of *Nisusia* in Montana, but they are too poorly preserved to warrant specific identification. In form and outline they resemble some specimens of *Nisusia burgessensis* Walcott.

Figured specimen, Mont. T1179a.

Horizon and locality.—Middle Cambrian. Damnation limestone: 20-2, Scapegoat Basin.

Genus WIMANELLA Walcott, 1908

Wimanella WALCOTT, 1908, Smithsonian Misc. Coll., vol. 53, no. 3, p. 98; WALCOTT, 1912, U. S. Geol. Survey, Mon. 51, p. 745; SCHUCHERT and COOPER, 1932, Peabody Mus. Nat. History, Mem., vol. 4, pt. 1, p. 50.

Outline probably subquadrate to subsemicircular, but usually distorted during preservation; hinge in most species shorter than or subequal to width of shell at middle; anterior commissure rectimarginate to slightly sulcate; profile biconvex, convexity of ventral valve usually the greater; ventral interarea longer than that of dorsal valve; surface smooth except for subdued growth lines and ridges; shell calcareous, thin.

Ventral valve: Posterior margins concave; beak incurved, obtusely rounded to pointed; interarea concave to flat, moderately apsacline to nearly orthocline; delthyrium open. Delthyrial cavity deep, confined posteriorly by inflected brim of delthyrium and divided at apex by low short septum; dental plates present or absent; adductor muscular scars confined to distinctly impressed pit at anterior margin of delthyrial cavity; diductor tracks usually straight, narrow, diverging anteriorly from each side of apical septum and apparently continuous with pallial trunks; pallial trunks broad, diverging sharply from each side of adductor muscular impression, and apparently not reaching margin of valve; fine radial striae present in marginal portion of valve.

Dorsal valve: Posterior margin straight, usually shorter than width of valve at middle; profile moderately convex or nearly flat; interarea flat, about 45° anacline; notothyrium open, wide; apex obscure, marginal;

sulcus obscure or distinct. Notothyrial cavity shallow, often with low platform continued toward front of valve as broad ridge; cardinal process absent or obscure; brachio-phores straight, projecting in line with notothyrial margins; radial striae present in marginal portion of valve.

Genotype, *Wimanella simplex* Walcott.

Species included.—The following species belong in *Wimanella* (emended): *Wimanella auralis* Bell, n. sp.; *Wimanella catulus* Walcott, 1917; *Orthis? highlandensis* Walcott, 1886; *Wimanella rossensis* Resser, 1938; *Billingsella saffordi* Walcott, 1905; *Wimanella simplex* Walcott, 1908; *Wimanella taei* Resser and Endo, 1937; ?*Wimanella shelbyensis* Walcott, 1908.

Distinguishing characters.—*Wimanella* is best characterized by its thin and smooth shell, subsemicircular outline, subequally to unequally biconvex profile, adductor muscular scar confined between anterior ends of diductor tracks, and straight brachio-phores projecting in line with notothyrial margins.

Discussion.—Walcott (1908, p. 98) originally proposed the genus *Wimanella* to embrace the older and smooth species of the Billingsellidae. His choice of *W. simplex* as the genotype was unfortunate, as pointed out by Schuchert and Cooper (1932, p. 51), because poor preservation of the type specimens in soft shale has almost totally obscured their internal morphology. The present study is based on all of Walcott's original material and a few specimens since collected from the Gordon shale in Montana.

The lot of specimens which includes the holotype of *W. simplex* was collected from U.S.N.M. loc. 4v on Gordon Creek, Montana. It comprises five ventral valves, two of which have counterparts, and one dorsal valve (pl. 33, fig. 18) whose posterior margin has been crushed against an adjacent ventral valve. Enough of the margin can be seen, however, to suggest that it was straight, and that the apex was marginal. One ventral counterpart (pl. 33, fig. 17), the only internal impression in the collection, shows widely divergent pallial trunks. No specimens in the type lot show either external or internal radial lines.

In addition to the type lot, there are in the United States National Museum a dozen specimens (U.S.N.M. 97073) also labeled

loc. 4v, which evidently have never been cited in the literature nor considered in connection with the description of *W. simplex*. Their occurrence in a somewhat more arenaceous matrix may explain why their convexity is much better preserved than that of the individuals in the type lot. There is little doubt that the specimens are conspecific with the holotype and its associated valves, although the ventral valves of the two lots differ somewhat in outline. The better preserved of these specimens (pl. 33, figs. 15, 19, 20) show that the ventral interarea is long and probably almost orthocline, the dorsal interarea short and somewhat anacline, the notothyrium wide and open, the notothyrial cavity shallow, with a platform from which a low median ridge extends anteriorly, the brachio-phores slender, projecting in line with the notothyrial margins, the interior of the shell, particularly near the margins, radially striated, and a cardinal process absent or obscure. The large callosities shown in one dorsal internal mold (pl. 33, fig. 20), are thought to be the result of unusual preservation.

A collection of *W. simplex* from the Gordon shale at U.S.N.M. loc. 4w on Youngs Creek, Montana, has yielded the specimen (pl. 33, fig. 21) which served as the basis for Schuchert and Cooper's (1932, p. 51) description of the ventral musculature of *Wimanella*. In this musculature the diductor tracks are adjacent posteriorly, the adductor pit being restricted to a position between their anterior ends. The musculature is similar to that in *Wimanella highlandensis* (Walcott) (pl. 33, fig. 24), this species and *W. simplex* being used by Schuchert and Cooper as cogenotypes of *Wimanella*. Associated with the above mentioned specimen (pl. 33, fig. 21) is an impression (pl. 33, fig. 14) of a delthyrial cavity without a deep adductor pit but with two narrow divergent ridges, presumably the diductor tracks, crossing it. The fact that only one of the many ventral valves of *W. simplex* collected from the Gordon shale shows evidence of a deep adductor pit and strongly incised diductor impressions suggests that this valve may be either very gerontic or morphologically abnormal.

Schuchert and Cooper (1932, p. 50) say

a study of all of his (Walcott's) species of *Wimanelia* at the U. S. National Museum shows the presence of faint radiating lines in shells conspecific with the genotype and in the actual types.

On the contrary, the specimens of *W. simplex* studied and figured by Walcott do not show radial striations of any kind, except, perhaps, on one internal mold (pl. 33, fig. 22). However, individuals in the lot of 12 topotypes (U.S.N.M. 97073) noted above show fine radial striations on the marginal portion of internal molds (pl. 33, figs. 15, 20). This type of striation is present in *Billingella* (pl. 34, figs. 7, 9; pl. 35, fig. 18) and presumably is of pallial origin. No external radial striation could be demonstrated on specimens from the type locality or adjacent localities in the Gordon shale. The specimens of *W. rossensis* Resser from the Ross Lake shale are obviously smooth except for growth lines. Evidently Walcott's diagnosis of a smooth shell for *Wimanelia* was correct, and Schuchert and Cooper interpreted radiating lines on internal molds as external features.

The Ross Lake shale member of the Cathedral dolomite⁸ in British Columbia was correlated by Walcott (1917a) with the Gordon shale of Montana on the basis of a similar fauna, characterized by the trilobite genus *Albertella*. Walcott (1917a, pl. 4, figs. 7c, 7-7b, and 8-8c) recognized *W. simplex* in the Ross Lake shale at U.S.N.M. localities 35c, 63j, and 63m, respectively. Later Resser (1938, p. 10) assigned Walcott's specimens to two new species, *W. rossensis* and *W. walcotti*. A study of the numerous excellent specimens from these localities has convinced the writer that only one species is represented, that the name *W. rossensis*, applied to valves beautifully preserved in limestone, should be retained, and the name *W. walcotti*, applied to flattened valves in the enclosing shale be rejected as a synonym. The details of the ventral morphology pre-

sented in the writer's emendation of the genus have been derived from the study of several beautiful, undistorted, ventral internal molds (pl. 33, figs. 1-5) in the collection of *W. rossensis* from U.S.N.M. loc. 63m' (limestone nodules in the shale of loc. 63m). The significant characters revealed by the molds are the distinctly rectangular adductor impression situated at the margin of the delthyrial cavity between the anterior ends of the diductor tracks but separated from them, and the short septum in the apex of the delthyrial cavity.

The writer believes that *Wimanelia highlandensis* (Walcott) and *W. simplex* Walcott are congeneric, as first proposed by Schuchert and Cooper (1932, p. 50), but he also believes that their analysis was based on atypical individuals of these two species. The ventral valve (pl. 33, fig. 21) from the Gordon shale has been discussed above. Two ventral internal molds (pl. 33, figs. 23, 25) associated with the holotype (pl. 33, fig. 24) of *W. highlandensis*, the specimen on which Schuchert and Cooper based their analysis, show a muscular and pallial arrangement fundamentally like that in the holotype, but not nearly so strongly impressed. They show a short median septum in the delthyrial cavity, a distinct but not deep adductor impression anterior to it, broad pallial trunks diverging widely from each side of the muscular impression, and barely perceptible diductor tracks diverging from the posterior end of the septum. This arrangement is essentially identical with that found in the ventral valve of *W. rossensis* (pl. 33, fig. 4). The presence of dental plates in *W. highlandensis* and their absence in *W. simplex* and *W. rossensis* is considered to be a specific difference, subordinate to the muscular and pallial arrangement. The radial ribbing on *W. highlandensis* (Schuchert and Cooper, 1932, p. 51) occurs on internal molds (pl. 33, fig. 25) and not on the surface of the shell, which is smooth except for growth lines.

WIMANELLA AURIALIS Bell, n. sp.

Plate 33, figure 6

This species is characterized, so far as can be determined, by complete similarity to *W. simplex*, except that the cardinal extremities project as acute mucronations or ears. It has been collected at two localities, where it oc-

⁸ In 1917 Walcott considered the Ross Lake shale to be a member of the Ptarmigan formation, but Deiss (1939b, p. 1002) has shown that the Ross Lake shale, characterized by the *Albertella* fauna, is a member of the Cathedral dolomite in Alberta and British Columbia. Collections from the Ross Lake shale at Ross Lake (Deiss, 1939b, p. 989, loc. C5c) and Mount Bosworth (Deiss, 1940, p. 747, loc. C6e), seen by the writer in June, 1940, contain excellent specimens of *Wimanelia rossensis* Resser.

curs in soft shales. The specimens, all ventral valves, are completely flattened, but the outline and surface characters are well preserved. *W. aurialis* is similar in outline to *Diraphora borealis* (Walcott) but differs from it in having a smooth shell.

Holotype, Mont. T1192a.

Horizon and locality.—Middle Cambrian. Wolsey shale: 40-2, Big Snowy Mountains; U.S.N.M. loc. 54z, probably the same locality; 45-1, Nixon Gulch.

WIMANELLA SIMPLEX Walcott
Plate 33, figures 13-22

Wimanella simplex WALCOTT, 1908, Smithsonian Misc. Coll., vol. 53, no. 3, p. 101, pl. 10, fig. 2; WALCOTT (part), 1912, U. S. Geol. Survey, Mon. 51, p. 748, pl. 89, figs. 2, 2a-e (not text fig. 64, p. 748); WALCOTT (part), 1917, Smithsonian Misc. Coll., vol. 67, no. 2, pl. 4, figs. 6, 6a-c (not figs. 7, 7a-c, 8, 8a-c).

Outline probably subquadrate to subsemicircular; hinge shorter than or subequal to but never longer than width of shell at middle; cardinal extremities obtusely angular to rounded; anterior commissure rectimarginate to slightly sulcate; profile unequally biconvex, the greater convexity of ventral valve accentuated by prominent umbo; ventral interarea longer than dorsal; surface smooth except for subdued growth lines and lamellae; shell thin.

Ventral valve: Posterior margins concave; interarea concave to flat, moderately apascline to orthocline; delthyrium open; beak incurved, obtusely pointed, obtusely rounded when flattened. Delthyrial cavity deep, confined posteriorly by inflected brim of delthyrium and divided at apex by low short septum; dental plates absent; adductor muscular scars confined to pit at anterior margin of delthyrial cavity; diductor muscular tracks straight, narrow, diverging anteriorly from apex of delthyrial cavity and apparently continuous with pallial trunks; pallial trunks broad, diverging rapidly from sides of adductor muscular impression and disappearing in marginal third of valve; each trunk composed of two parallel furrows separated by a ridge; radial striae present in marginal portion of valve.

Dorsal valve: Posterior margin straight, considerably shorter than width of valve at middle; interarea flat, about 45° anacline; notothyrium open; apex obscure, marginal;

profile moderately convex or nearly flat; sulcus obscure or distinct. Notothyrial cavity shallow, often with low platform continued toward front of valve as a broad ridge; cardinal process apparently absent, its presence possibly being indicated by a low linear elevation; brachioophores straight, slender, projecting in line with notothyrial margins; radial striae present in marginal portion of valve.

Dimensions (mm.)

	Length	Width	Hinge width	L/W
Ventral valves:				
U.S.N.M. 52278a	6.17	8.7	7.7	0.71
U.S.N.M. 97073b	8.0	8.7	7.3	0.92
Dorsal valves:				
U.S.N.M. 97073a	10.7	12.7	13.3	0.84
U.S.N.M. 97073d	5.0	7.3	6.3	0.68

Holotype, U.S.N.M. 52278a; paratypes, U.S.N.M. 52278b, 52277a-d; hypotypes, U.S.N.M. 52278c, 52277e-f, 97073a-d, and Mont. T1184a.

Horizon and locality.—Middle Cambrian. Gordon shale: 20-1c, Scapegoat Basin; 23-1, Ahorn Creek; 53-1 (?), Kid Mt.; U.S.-N.M. localities 4q, ridge between Gordon and Youngs Creeks; 4v, Gordon Creek; 4w, Youngs Creek.

Distinguishing characters.—*Wimanella simplex* is best characterized by its convex ventral valve, having a prominent umbo and incurved beak, its moderately convex or nearly flat and sulcate dorsal valve, its compound (?) pallial trunks, and its lack of dental plates.

Discussion.—Walcott (1917b, p. 70), and later Resser (1938, p. 10) distinguished three species of *Wimanella* (*W. catulus* Walcott, *W. rossensis* Resser, and *W. walcotti* Resser) from the Cambrian rocks of Alberta and British Columbia, entirely on the basis of external shell form. The ventral valves in the type lot of specimens of *W. simplex* are flattened in soft shale and are subsemicircular in outline. The ventral valves in another group of specimens from the type locality occur only slightly flattened in a more arenaceous phase of the shale and are subquadrate in outline. The ventral valves from Youngs Creek are flattened in the soft Gordon shale but tend to be elongate-subrectangular. Apparently more than one species is indicated by these differing shell outlines.

However, among the numerous flattened ventral valves in the collections from the Ross Lake shale of Alberta and British Columbia, all three of the above-mentioned outlines are duplicated, as well as all transitions between them. In addition, many of the valves are distinctly asymmetrical, and in every instance the lines of foliation in the shale can be shown to parallel the direction of distortion in the shell. Likewise, the lines of foliation in the rock parallel the longitudinal axis of elongate valves and the transverse axis of excessively wide valves. Ventral valves, identical in all respects except outline and profile with those in the shale, occur in limestone nodules in the shale, are uniformly subequal in length and width, and are strongly convex. The discrepancy in outline between dorsal valves in the shale and in the limestone is less marked, evidently because the dorsal valves were originally only moderately convex. It must be concluded, therefore, that the combination of vertical compression and lateral distortion resulting from rock deformation has produced widely different outlines in convex shells whose outlines originally were similar. The writer's conclusion is that *W. catulus*, *W. rossensis*, and *W. walcotti* cannot be distinguished from *W. simplex* or from each other by means of shell outline. They are names applied to variations in shell form produced by mechanical forces subsequent to the burial of the shells. However, *W. rossensis* Resser may profitably be retained as a valid species because its well-defined internal characters cannot be compared with the poorly preserved structures in the specimens of *W. simplex* from the Gordon shale of Montana. In the writer's opinion *W. walcotti* Resser is a synonym of *W. rossensis*. The type specimens of *W. catulus* Walcott are too few and poorly preserved for adequate comparison with other species; it is reported from the Lower Cambrian, Mount Whyte formation, but almost certainly is Middle Cambrian in age.

Genus *DIRAPHORA* Bell, n. gen.

(Gr. *δεῖπας*, ridge; *φόρος*, bear)

Plate 33, figure 7

The genus *Diraphora* is proposed to embrace the primitive species of the Billingsellidae that apparently are like *Wimanelle* ex-

cept that they possess radial surface ornamentation.

Genotype, *Eoorthis bellicostata* Walcott, 1924, Smithsonian Misc. Coll., vol. 67, no. 9, p. 505, pl. 113, figs. 8-14.

The following species are referred to *Diraphora*: *Billingsella? anomala* Walcott, 1905; *Billingsella? appalachia* Walcott, 1905; *Eoorthis bellicostata* Walcott, 1924; *Wimanelle borealis* Walcott, 1924; *Wimanelle maladenensis* Resser, 1939; *Protorthis nautes* Walcott, 1905; *Billingsella striata* Walcott, 1905.

Discussion.—A study of the primitive billingsellids represented in the United States National Museum collection shows that a number of Middle Cambrian species that heretofore have been assigned to a variety of genera apparently differ from *Wimanelle*, as it is defined in this paper, only in possessing costellae. The dorsal cardinalia appear to be nearly identical in the two genera, but the delthyrial septum, if present at all in *Diraphora*, is less strongly developed than in *Wimanelle*. All the species of *Diraphora* are thin-shelled, and most are represented by specimens poorly preserved in shale. The genotype was adequately described and figured by Walcott, but an additional ventral valve, showing the diductor tracks, continuous with the pallial trunks, is illustrated here (pl. 33, fig. 7).

DIRAPHORA STRIATA (Walcott)

Plate 33, figures 8-11

Billingsella striata WALCOTT, 1905, U. S. Nat. Mus., Proc., vol. 28, p. 245; 1912, U. S. Geol. Survey, Mon. 51, p. 764, pl. 86, figs. 4, 4a-c.

Ventral valve: Outline subquadrate; posterior margins slightly concave; beak obtusely pointed; cardinal extremities obtusely angular, lateral and anterior margins smoothly rounded; profile strongly convex, greatest convexity in posterior third of valve; beak strongly incurved; interarea long, concave, somewhat apsacline to nearly orthocline, depending on amount of concavity; delthyrium apparently open; surface evenly subdued costellate; shell thin, calcareous. Dental plates absent; teeth not observed; floor of deep delthyrial cavity crossed by two anteriorly trending narrow, divergent furrows (diductor tracks) which merge with the more divergent pallial trunks at margin of delthyrial cavity; each

pallial trunk is composed of two narrow furrows with a broad rounded ridge between them; pallial trunks disappear at margin of valve without bifurcation; marginal brim of valve closely grooved or plicate.

Dorsal valve: Represented by a single fragmentary exterior. Gently convex or flat, sulcate, closely costellate, filate.

Holotype, U.S.N.M. 52279a; paratypes, U.S.N.M. 52279b-d; hypotype, U.S.N.M. 52279e.

Horizon and locality.—Middle Cambrian. Meagher limestone: U.S.N.M. loc. 149a, Pole Creek.

Distinguishing characters.—*Diaphora striata* is characterized by its strongly convex ventral valve with incurved beak and apsacline to orthocline concave interarea.

Discussion.—The shell is quite thin. Because the outer surfaces of the shells adhere tenaciously to the matrix, internal molds are common; almost all specimens in the collection are internal molds of ventral valves. The single fragmentary dorsal exterior is so poorly preserved that its assignment to this species is uncertain.

Study of the ventral internal molds shows the palintrope to have been thick, apsacline to orthocline, strongly curved from apex to anterior margin, and unsupported by callus or dental plates. The teeth were not ob-

served. Apparently the shell is continuous as a rim around the posterior end of the delthyrial cavity.

DIRAPHORA? sp.

Plate 33, figure 12

Known only from three ventral internal molds from different localities. Outline subquadrate; posterior margins concave; cardinal extremities obtusely angular; profile moderately convex, highest in posterior third of valve; apex slightly incurved; delthyrial cavity deep, bounded anteriorly by a low ridge; dental plates absent; diductor tracks straight, narrow, slightly divergent and continuous with faint pallial trunks; adductor scars present at anterior margin of delthyrial cavity; surface of molds covered by very fine radiating striae; more prominent ridges on molds indicate that valves were multicostellate.

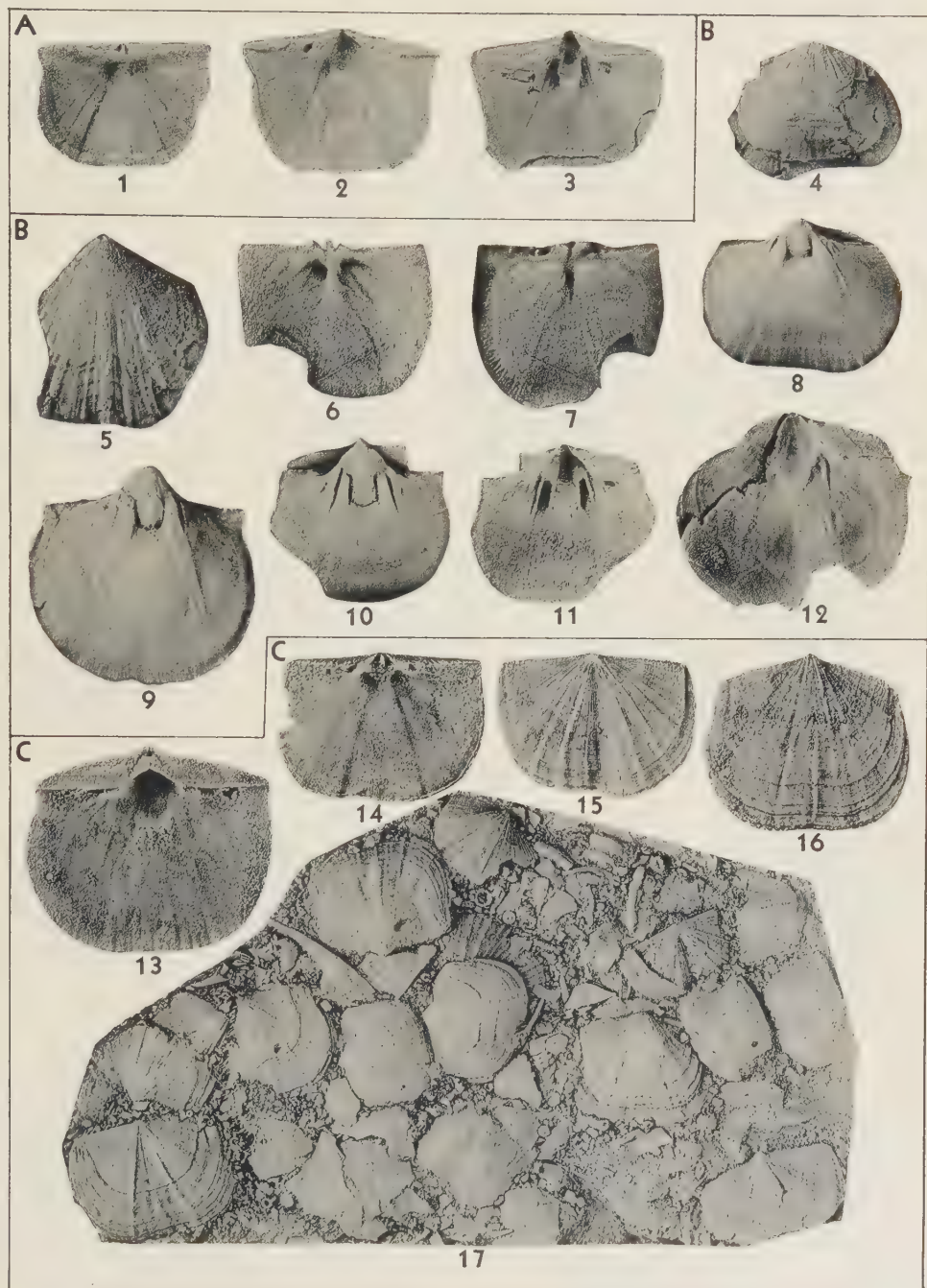
Figured specimen.—Mont. T1183a.

Horizon and locality.—Middle Cambrian. Lower Meagher limestone: 47-2, Beaver Creek; U.S.N.M. localities 9h (52274), Beaver Creek, and 159 (unnumbered), north of West Gallatin River.

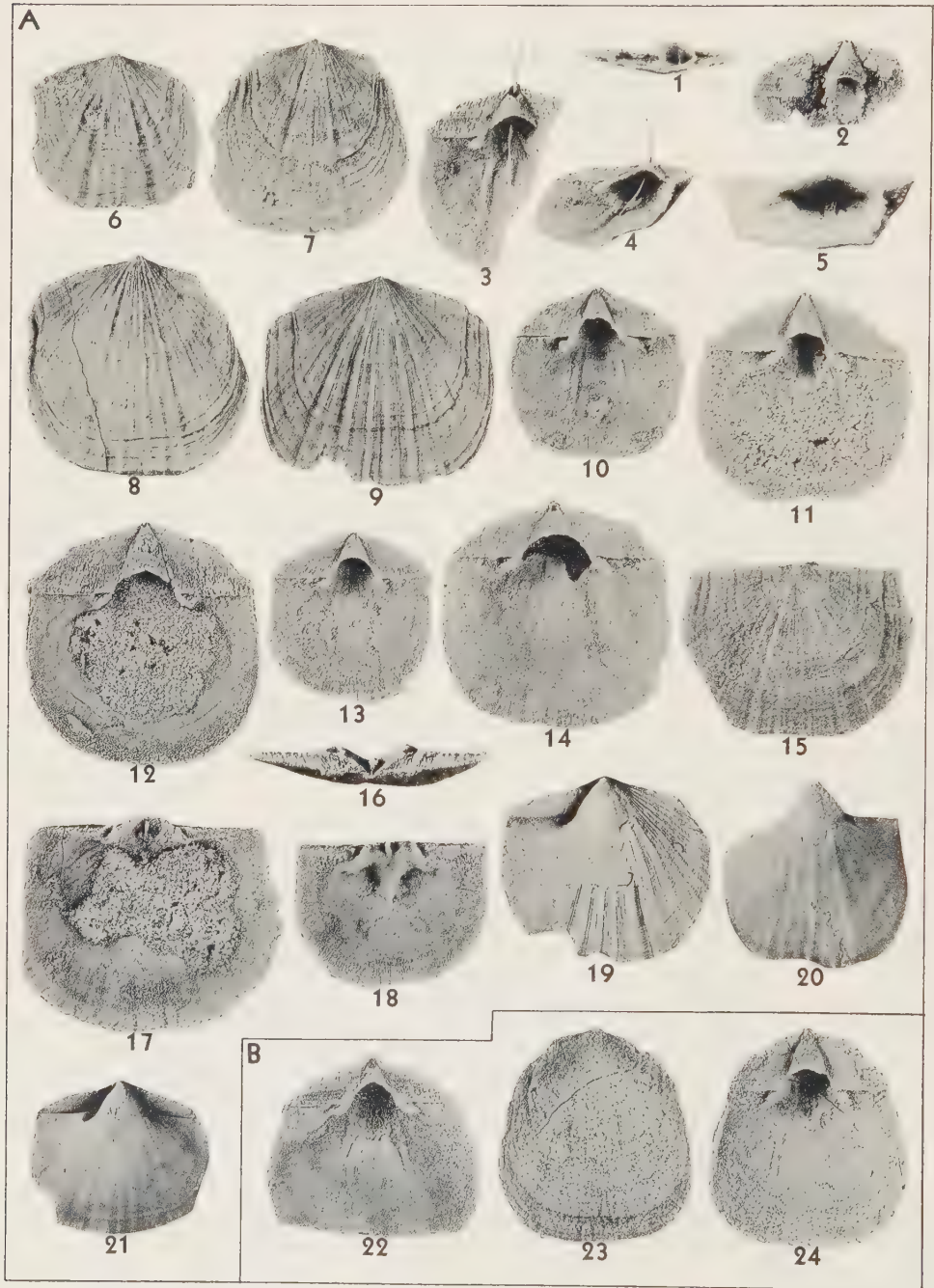
Discussion.—The molds are assigned tentatively to *Diraphora* because they lack dental plates, the diductor tracks are narrow

EXPLANATION OF PLATE 34

- FIGS. 1-3—*Billingsella alata* Bell, n. sp. 1, 2, Syntypes; interiors of incomplete dorsal and ventral valves, Mich. 20809a-b, $\times 3$, loc. M1-4. 3, Figured specimen (Mon. 51, pl. 86, fig. 3m, as *Billingsella plicatella*); interior of nearly complete ventral valve, showing high pseudospondylium and strong pallial trunks, U.S.N.M. 52266a, $\times 3$, loc. 4j. Upper Cambrian: Snowy Range formation and Dry Creek shale. (p. 246)
- 4-12—*Billingsella plicatella* Walcott. 4, Paratype (Mon. 51, pl. 86, fig. 3c); exterior of small sulcate ventral valve, U.S.N.M. 52263d, $\times 3$, loc. 158. 5, Paratype (Mon. 51, pl. 86, fig. 3); exterior of incomplete ventral valve, showing fila flexed toward apex at junction with median costella, U.S.N.M. 52263a, $\times 3$, loc. 158. 6, 7, Paratype (Mon. 51, pl. 86, fig. 3l); clay squeeze and dorsal internal mold from which it was made, showing strong cardinal process and high ridge anterior to it, U.S.N.M. 52263l, $\times 3$, loc. 158. 8, Paratype (Mon. 51, pl. 86, fig. 3j); ventral internal mold, showing adductor track strongly constricted posteriorly, U.S.N.M. 52263j, $\times 3$, loc. 158. 9, Holotype (Mon. 51, pl. 86, fig. 3i); ventral internal mold, showing beautifully preserved pallial impressions, U.S.N.M. 52263i, $\times 3$, loc. 158. 10, 11, Figured specimen; ventral internal mold and clay squeeze made from it, showing high pseudospondylium, Mont. T1177a, $\times 3$, loc. 46-3. 12, Figured specimen; incomplete ventral interior, showing distinct pallial markings, and adductor track strongly constricted posteriorly by encroaching diductor scars, Mont. T1177b, $\times 3$, loc. 46-3. Upper Cambrian: Dry Creek shale. (p. 218)
- 13-17—*Billingsella exasperata* Bell, n. sp. 13, Syntype; interior of ventral valve, Mont. T1172a, $\times 3$, loc. 44-2. 14, 15, Syntypes; interior and exterior views of two dorsal valves, Mont. T1172b-c, $\times 3$, loc. 44-2. 16, Syntype; exterior of ventral valve, Mont. T1172d, $\times 3$, loc. 44-2. 17, Figured specimens; small slab of limestone bearing numerous dorsal and ventral valves of this species, Mich. 20807, $\times 2$, loc. M1-4. Upper Cambrian: Dry Creek shale and Snowy Range formation. (p. 246)



Bell, Cambrian Brachiopoda



Bell, Cambrian Brachiopoda

and continuous with the pallial trunks, and the surfaces of the shells were costellate.

Genus BILLINGSSELLA Hall, 1892

Billingsella HALL, 1892, Paleontology New York, vol. 8, pt. 1, p. 230; WALCOTT, 1912, U. S. Geol. Survey, Mon. 51, p. 749; SCHUCHERT and COOPER, 1932, Peabody Mus. Nat. History, Mem., vol. 4, pt. 1, p. 48; ULRICH and COOPER, 1938, Geol. Soc. America, Special Paper. 13, p. 72.

The excellent discussions by Schuchert and Cooper (1932, p. 48) and Ulrich and Cooper (1938, p. 72) have made *Billingsella* one of the best known Cambrian genera. The present study can add little information of generic significance.

The beautifully silicified specimens on which Ulrich and Cooper based their description of *B. perfecta* were obtained from the Teton Mountains in Wyoming, about 100 miles south of Crowfoot Ridge, Yellowstone National Park, from which were obtained the only silicified specimens of *Billingsella* in the writer's collections. At its type locality *B. perfecta* exhibits remarkably little variation in its characters. This is not true, however, of the billingsellids from Montana.

The writer had at his disposal four collections of *Billingsella* from measured sections, and in addition numerous United States National Museum collections from isolated and not accurately designated localities. From a study of these specimens, certain additions can be made to the knowledge of the development of the genus in Montana and adjacent areas. *Billingsella* is widespread

geographically in Montana but limited to a narrow stratigraphic zone in the middle Upper Cambrian. It is the predominant brachiopod at almost all localities where it occurs, being associated with few representatives of *Eoorthis*, *Huenella*, *Ocnerorthis*, and *Otusia*. The most striking characteristic of *Billingsella*, as it is developed in south-central Montana and northwestern Wyoming, is the variability in form and ornamentation of the ventral valve. The ventral valve is characterized by a strongly convex to nearly flat profile; subcircular, subquadrate, transverse or elongate subrectangular outline; long or short interarea, relative to its width; long and convex, or short and flat deltidium; and strongly or weakly impressed muscular and pallial marks. In contrast, the dorsal valve varies almost not at all in its form and internal markings. The surface markings vary greatly in the relative development of costellae, parvicostellae, and fila.

Although certain of the above mentioned characters consistently occur together in such a way as to distinguish groups of shells that can be designated as of specific rank, there are many shells that partake of the characters of more than one of the specific groups. Shells from a single locality may vary widely from a norm, yet apparently identical forms are present at widely separated localities. The species of *Billingsella* described and illustrated in this paper are admittedly artificial in their composition and are presented only as representative nodes, from which considerable variation may be expected.

EXPLANATION OF PLATE 35

- FIGS. 1-21—*Billingsella perfecta* Ulrich and Cooper, 1, 2, Hypotype; two views of a fragmental ventral valve, showing details of the deltidium, Mont. T1170a, $\times 3$, loc. 44-2. 3, 4, Hypotype; two views of an incomplete ventral valve, with hair passed through minute pedicle tube confined to the deltidium, Mont. T1170b, $\times 3$, loc. 44-2. 5, Enlarged view of same specimen tilted so as to see into apex, showing apical septum, Mont. T1170b, $\times 5$, loc. 44-2. 6-9, Hypotypes; ventral exteriors, showing slight variation in ornamentation, Mont. T1170c-f, $\times 3$, loc. 44-2. 10-14, Hypotypes; ventral interiors, showing slight variation in form of deltidium, Mont. T1170g-k, $\times 3$, loc. 44-2. 15, Hypotype; dorsal exterior, Mont. T1170l, $\times 3$, loc. 44-2. 16, 18, Hypotype; posterior ($\times 4$) and interior ($\times 3$) views of a dorsal valve having especially stout brachiophores and cardinal process, Mont. T1170m, loc. 44-2. 17, Hypotype; dorsal interior, showing strong chilidium, Mont. T1170n, $\times 3$, loc. 44-2. 19, 20, Hypotypes; partial and incomplete ventral internal molds, Mich. 20801a-b, $\times 3$, loc. M1-4. 21, Hypotype; ventral internal mold, Mich. 20808a, $\times 3$, loc. M2-1. Upper Cambrian: Dry Creek shale and Snowy Range formation. (p. 247)
- 22-24—*Billingsella perfecta pyramiformis* Bell, n. var. 22, Paratype; ventral interior, showing short deltidium, Mont. T1180b, $\times 3$, loc. 44-2. 23, 24, Holotype; exterior and interior views of a complete ventral valve with a long interarea and deltidium, Mont. T1180a, $\times 3$, loc. 44-2. Upper Cambrian: Dry Creek shale. (p. 247)

Apparently all occurrences of *Billingsella* in Montana and adjacent areas are essentially of the same age, and mark the greatest single period of orthid development in the Cambrian of this area. *Billingsella* occurs almost universally associated with *Eoorthis*, the subzones characterized by these genera in the upper Mississippi Valley province not being recognizable in Montana.

BILLINGSSELLA ALATA Bell, n. sp.

Plate 34, figures 1-3

Billingsella plicatella Walcott. WALCOTT (part), 1912, U. S. Geol. Survey, Mon. 51, pl. 86, figs. 3m, 3n (?).

Species known only from imperfect interiors. Outline transversely subrectangular with greatest width at hinge; cardinal extremities acutely angular, alate; profile moderately and subequally biconvex; surface apparently costellate and parvicostellate.

Ventral valve: Posterior margins slightly concave; apical angle 160° ; interarea short in proportion to width, orthocline; adductor scar narrows rapidly and uniformly toward apex of valve; pseudospondylium high for the genus, pallial trunks straight, narrow, divergent.

Dorsal valve: Cardinal process strong; no muscular or pallial marks observed.

Dimensions (mm.)

	Length	Width	Hinge width	L/W
Ventral valve:				
Mich. 20809b....	7.0	8.2	9.0	0.85
Dorsal valve:				
Mich. 20809a....	5.7	8.0?	8.0?	0.71

Syntypes, Mich. 20809a-b; figured specimen: U.S.N.M. 52266a.

Horizon and locality.—Upper Cambrian. Dry Creek shale: 44-2 (?), Crowfoot Ridge, 46-3, Nixon Gulch; U.S.N.M. loc. 4j, head of Deep Creek, Yellowstone Park. Snowy Range formation: M1-4, Beartooth Butte.

Discussion.—The only other species of *Billingsella* that characteristically possesses alate cardinal extremities is *B. corrugata* Ulrich and Cooper, from which *B. alata* differs distinctly in surface ornamentation and in being decidedly more convex and smaller.

BILLINGSSELLA EXASPERATA Bell, n. sp.

Plate 34, figures 13-17

Billingsella plicatella Walcott. WALCOTT (part), 1912, U. S. Geol. Survey, Mon. 51, pl. 86, figs. 3b, 3f.

Outline subquadrate or transversely subrectangular; hinge line equal to, or slightly less than width of valve at middle; cardinal extremities rectangular to obtusely angular; profile moderately and subequally biconvex; anterior commissure sulcate; surface paucicostellate, strongly parvicostellate, and filate.

Ventral valve: Posterior margins straight or slightly convex; apical angle about 150° ; umbo not noticeably swollen, anterior margin straight or slightly emarginate; flat median fold scarcely discernible, bordered by shallow furrows, and may disappear and be replaced anteriorly by shallow sulcus; interarea slightly longer than that in dorsal valve, very wide in proportion to length, flat, orthocline; apically perforated deltidium covers more than half of delthyrium. Costellae subdued, rounded; fila numerous; growth lamellae strong marginally. Adductor track wide, with subparallel sides; pallial trunks faintly impressed.

Dorsal valve: Outline transversely subrectangular; posterior margins straight; apical angle about 170° ; cardinal extremities rectangular to obtusely angular; anterior margin emarginate, strongly sulcate; sulcus rounded in cross section, bordered by pair of strong costellae diverging from apex; interarea short, flat, strongly anacline; notothyrium open so far as observed. Surface paucicostellate, costellae decreasing in size from edge of sulcus to posterior margins; sulcus and flat intercostellate spaces strongly parvicostellate; fila distinct, close together. Notothyrial platform low; cardinal process and brachiophores short, stout; fine radiating ribs, presumably of pallial origin, present in marginal portion of shell.

Dimensions (mm.)

	Length	Width	Hinge width	L/W
Ventral valves:				
Mont. T1172a...	9.5	11.5	10.8	0.83
Mont. T1172d...	8.3	9.8	8.7	0.85
Dorsal valves:				
Mont. T1172b...	6.8	9.8	9.0	0.69
Mont. T1172c...	6.3	9.3	8.7	0.68

Syntypes, Mont. T1172a-d; figured specimens, Mich. 20807.

Horizon and locality.—Upper Cambrian. Dry Creek shale: 44-2 Crowfoot Ridge; 46-3 (?), Nixon Gulch; U.S.N.M. localities 4j, 62r, 302f, 302g (?), all in Yellowstone Park;

147a, 151, 152, all in Bridger Range; 150a, 158, near Hillsdale; 302r (?), near Princeton. Snowy Range formation: M1-4, Beartooth Butte.

Discussion.—*Billingsella exasperata* is most similar to *B. weedi* but differs from it in outline and ornamentation and in having a faint ventral fold. Its convexity is intermediate between the slight convexity of *B. perfecta* and the strong convexity of *B. plicatella*.

BILLINGSSELLA PERFECTA

Ulrich and Cooper

Plate 35, figures 1–21

Billingsella coloradoensis (Shumard). WALCOTT (part), 1912, U. S. Geol. Survey, Mon. 51, pl. 85, figs. 1a, 1g, 1l, 1o, 1t, 1w.

Billingsella pepina (Hall). SCHUCHERT and COOPER, 1932, Peabody Mus. Nat. History, Mem., vol. 4, pt. 1, pl. 1, figs. 6, 13, 19, 21, 25.

Billingsella perfecta ULRICH and COOPER, 1936, Jour. Paleontology, vol. 10, no. 7, p. 619; 1938, Geol. Soc. America, Special Paper 13, p. 74, pl. 7B, figs. 11–21.

Billingsella perfecta probably is the most completely known species of the genus and for practical purposes will likely come to typify *Billingsella*. The silicified specimens of *B. perfecta* from the type locality in the Teton Mountains, Wyoming, have uniformly thicker valves than the similarly preserved specimens from Crowfoot Ridge and have more deeply impressed muscular and pallial markings. The type specimens are remarkably uniform in shape and ornamentation, whereas those from Crowfoot Ridge vary within narrow limits. The surface ornamentation on the Montana specimens is better preserved, showing details visible on only a few of the types. The following emended characterization of the species is intended to include the additional information regarding variability and surface ornamentation derived from the present study.

Ventral valve: Outline subquadrate, subcircular, or elongate subrectangular; posterior margins slightly to strongly convex outward; hinge equal to or less than width of valve at middle; cardinal extremities obtusely angular or rounded; convexity slight, greatest at umbo; posterolateral flanks flattened or slightly concave; low flat median fold, defined by pair of furrows, disappears anteriorly, giving way in some valves to a faint sulcus; interarea orthocline, long with respect to width; apically perforated del-

tidium strongly convex, covering a third to one-half the delthyrium; costellae narrow, rounded, strongest on fold; intercostellate spaces flat, twice width of costellae, parvicostellate; fila vague or distinct, close together; growth lamellae present or absent. Interior rather variable; adductor track long or short, slightly constricted posteriorly; pallial trunks narrow, straight, slightly divergent anteriorly.

Dorsal valve: Outline transversely subrectangular; hinge equal to or slightly less than width of valve at middle; cardinal extremities rectangular, obtusely angular, or rounded; convexity even, greater than in ventral valve; sulcus concave or flat-bottomed with steep sides, demarcated by pair of strong costellae diverging from apex; interarea vertical or strongly anacline; chilidium well-developed; costellae subded in sulcus, distinct and close together on flanks; parvicostellae between costellae, particularly numerous in sulcus; fila faint or distinct, numerous. Brachioophores short, stout, oblique; notothyrial platform well-developed, usually extending anteriorly as axial ridge toward center of valve.

Dimensions (mm.)

	Length	Width	Hinge width	L/W
Ventral valves:				
Mont. T1170h...	10.0	10.0	9.3	1.00
Mont. T1170i...	11.3	10.8	10.3	1.05
Dorsal valves:				
Mont. T1170m...	6.7	9.0	8.7	0.74
Mont. T1170n...	9.7	12.7?	10.3	0.76

Hypotypes, Mont. T1170a–n, Mich. 20-801a–b, Mich. 20808a.

Horizon and locality.—Upper Cambrian. Dry Creek shale: 44-2, Crowfoot Ridge; 46-3, Nixon Gulch; U.S.N.M. localities 62r, 151e, 302g, all in Yellowstone Park; 4e, head of Jackson Creek, Teton Mountains, Wyoming; 154, near Hillsdale. Snowy Range formation: M1-4, Beartooth Butte; M2-1, Republic Mt.

BILLINGSSELLA PERFECTA PYRIFORMIS

Bell, n. var.

Plate 35, figures 22–24

This variety, known only from ventral valves, differs from *Billingsella perfecta* in having a more convex and elongate shell, greatest width in anterior third of valve, more convex posterior margins, relatively

longer interarea, and more common rugose lamellae. In this variety the deltidium is either very convex and covers more than one-half of the delthyrium, or it is slightly convex and covers less than one-third of the delthyrium.

Dimensions (mm.)

	Length	Width	Hinge width	L/W
Ventral valve:				
Mont. T1180a...	10.0	9.3	7.6	1.08

Holotype, Mont. T1180a; paratype, Mont. T1180b.

Horizon and locality.—Upper Cambrian. Dry Creek shale: 44-2 and U.S.N.M. loc. 302g, both on *Crowfoot Ridge*.

Discussion.—The comparatively slight difference in structure between these valves and those of *B. perfecta*, together with the fact that no dorsal valves and only a few ventral valves are known, has led to the proposal of a variety of *B. perfecta* rather than a new species.

BILLINGSSELLA PLICATELLA Walcott

Plate 34, figures 4-12

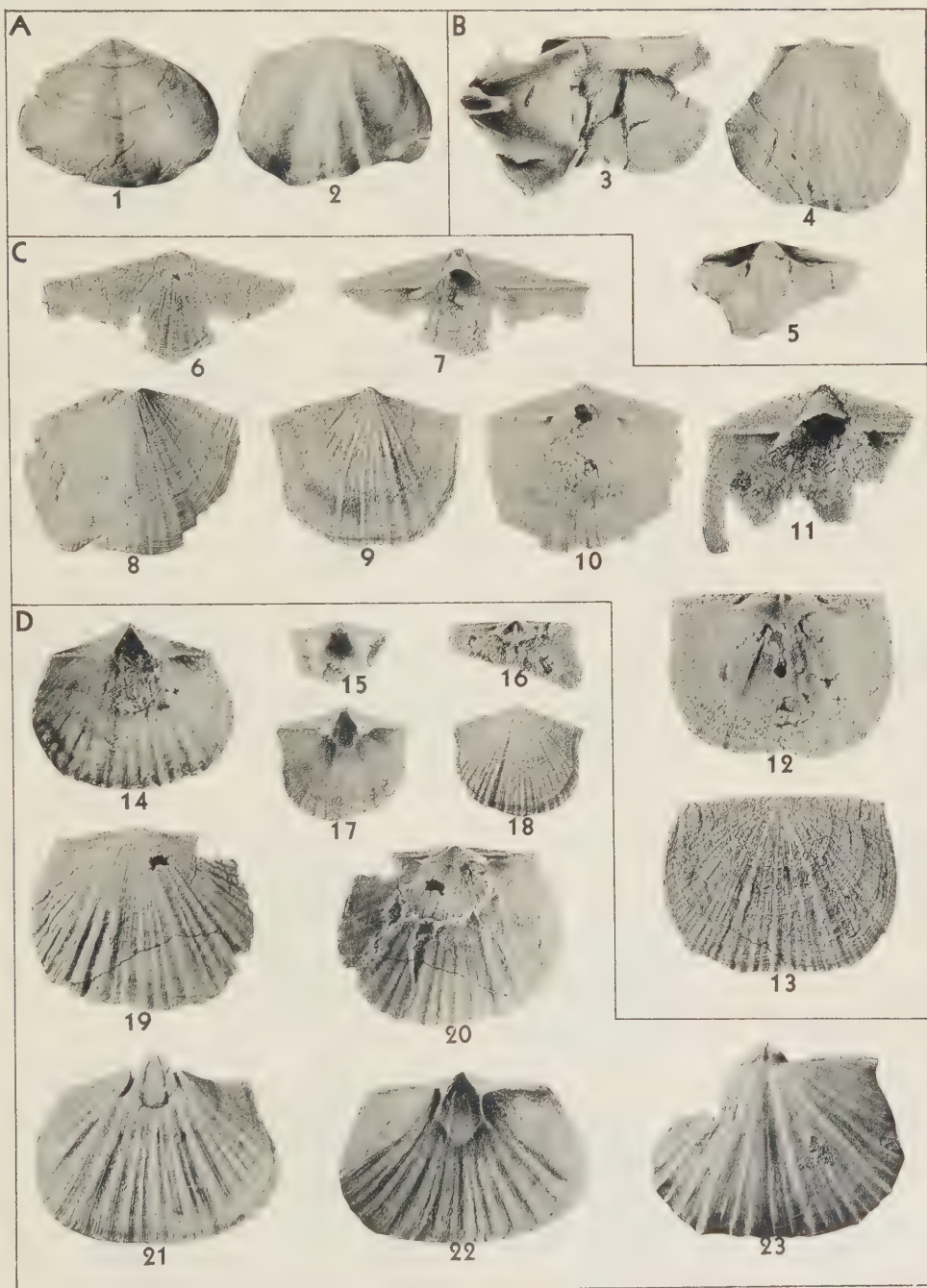
Billingsella plicatella WALCOTT, 1905, U. S. Nat. Mus., Proc., vol. 28, p. 240; WALCOTT (part), 1912, U. S. Geol. Survey, Mon. 51, p. 759, pl. 86, figs. 3, 3a, 3c, 3e (?), 3g-l (not figs. 3b, 3f = *B. exasperata* Bell, n. sp.; 3m, 3n = *B. alata* Bell, n. sp.; 3d = *Eoorthis* sp.)

Outline subquadrate or subcircular; hinge equal to or slightly less than width of shell at middle; cardinal extremities obtusely rounded; profile unequally biconvex, convexity of ventral valve being considerably the greater; surface multicostellate, with numerous parvicostellae in interspaces, crossed by numerous distinct fila.

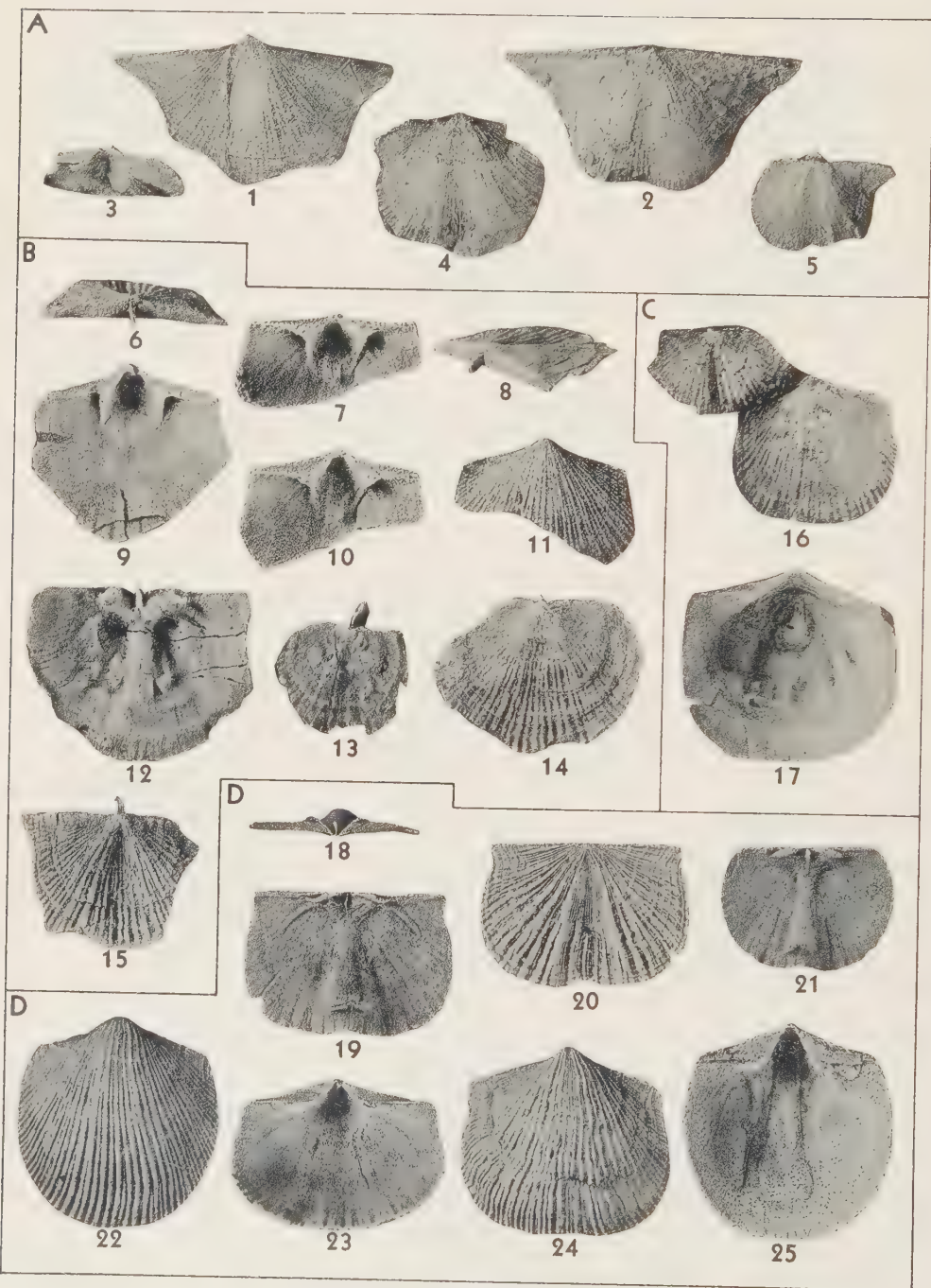
Ventral valve: Profile evenly and strongly convex, greatest height at middle of valve; sulcus present or absent; interarea longer than dorsal, orthocline or slightly apsacline; character of deltidium unknown; two strong costellae diverge anteriorly from apex, a single costella of equal strength being implanted between them; fila flex sharply toward apex at junction with three major costellae; costellation subdued and parvicostellae numerous in sulcate valves. Adductor track strongly constricted posteriorly by excessively large diductor impressions, abruptly expanded anteriorly into deeply incised subquadrate impression, and raised above floor of valve on a deposit of callus; vascula media (Öpik, 1934, pp. 38-40) strongly impressed, straight, originating lateral to rectangular adductor scar at anterior margins of diductor impressions, diverging at about 30° and bifurcating near margin of valve into inner secondary vascula which coalesce at median line of valve, and lateral secondary

EXPLANATION OF PLATE 36

- FIGS. 1, 2—*Huenella abnormis* (Walcott). Holotype (Mon. 51, pl. 103, fig. 2a); ventral exterior, U.S.N.M. 52462b, $\times 3$, loc. 4j. 2, Paratype (Mon. 51, pl. 103, fig. 2e); dorsal exterior, U.S.N.M. 52462e, $\times 3$, loc. 4j. (see also 3) Upper Cambrian: Dry Creek shale. (p. 254)
- 3-5—*Billingsella weedi* (Walcott). 3, Syntype (Walcott, 1924, pl. 120, fig. 7, as *Huenella weedi*); dorsal exterior, associated with an incomplete ventral interior of *Huenella abnormis*, U.S.N.M. 69798c, $\times 3$, loc. 302g. 4, Syntype (Walcott, 1924, pl. 120, fig. 8, as *Huenella weedi*); incomplete ventral exterior, U.S.N.M. 69798a, $\times 3$, loc. 302g. 5, Hypotype; incomplete ventral internal mold, U.S.N.M. 69798d, $\times 3$, loc. 302g. Upper Cambrian: Dry Creek shale. (p. 250)
- 6-13—*Billingsella radiata* Bell, n. sp. 6, 7, Syntype; exterior and interior views of a fragmental ventral valve, Mont. T1171a, $\times 3$, loc. 44-2. 8, Figured specimen; incomplete ventral exterior, Mich. 20802a, $\times 3$, loc. M2-1. 9, Syntype; ventral exterior, Mont. T1171b, $\times 3$, loc. 44-2. 10, 11, Syntypes; ventral interiors, Mont. T1171c-d, $\times 3$, loc. 44-2. 12, 13, Syntypes; interior and exterior of two dorsal valves, Mont. T1171e-f, $\times 3$, loc. 44-2. Upper Cambrian. Dry Creek Shale and Snowy Range formation. (p. 250)
- 14-23—*Eoorthis remnicha* (Winchell). 14, Figured specimen; ventral interior, Mont. T1173a, $\times 1.5$, loc. 44-2. 15, Figured specimen; interior of ventral apex, showing apical callosity, Mont. T1173e, $\times 3$, loc. 44-2. 16, Figured specimen; incomplete dorsal interior showing exceptionally well developed cardinal process, Mont. T1173d, $\times 3$, loc. 44-2. 17, 18, Figured specimen; interior and exterior of a ventral valve, Mont. T1173c, $\times 3$, loc. 44-2. 19, 20, Figured specimen; dorsal exterior and interior, Mont. T1173b, $\times 2$, loc. 44-2. 21, 22, Figured specimen; ventral internal mold and clay squeeze made from it, showing strong dental plates and high pseudospondylium, Mich. 20800a, $\times 3$, loc. M2-1. 23, Figured specimen; incomplete dorsal internal mold, showing adductor muscular impressions and strong cardinal process, Mont. T1175a, $\times 3$, loc. 46-3. Upper Cambrian: Dry Creek shale and Snowy Range formation. (p. 254)



Bell, Cambrian Brachiopoda



Bell, Cambrian Brachiopoda

vascula which parallel margin of valve, becoming the vascula arcuata.

Dorsal valve: Represented in type lot only by immature specimens from which finer ornamentation has been removed by abrasion. Outline transversely subrectangular; anterior margin sulcate; interarea short, flat, strongly anacline; surface paucicostellate. Notothyrial platform high, extending anteriorly as strong ridge; cardinal process and brachiophores short and stout. Marginal brim of both valves abruptly deflected outward.

Dimensions (mm.)

	Length	Width	Hinge width	L/W
Ventral valve:				
U.S.N.M. 52263i.	10.3	10.5	8.5	0.98
Dorsal valve:				
U.S.N.M. 52263l.	7.2	9.6	9.0	0.75

Holotype, U.S.N.M. 52263i; paratypes, U.S.N.M. 52263a, b, d, g, h, j-l; figured specimens, Mont. T1177a-b.

Horizon and locality.—Upper Cambrian. Dry Creek shale: 46-3, Nixon Gulch; U.S.N.M. localities 4j, Yellowstone Park; 150a, 153, 153a (?), 154, 156b, 157, 158, all near Hillsdale; 151, 151a (?), 152, all in Bridger Range; 302r (?), near Princeton. Snowy Range formation: M2-1, Republic Mt.

Distinguishing characters.—*Billingsella plicatella* is characterized by its ventral valve being considerably more convex than the dorsal, adductor scar strongly constricted posteriorly, pseudospondylium and pallial marks exceptionally well developed, fila flexed toward apex at junction with three major costellae on ventral valve, and marginal brim of both valves slightly deflected outward.

Discussion.—*Billingsella plicatella* is readily separated from all associated species of the genus by the extreme convexity of the ventral valve.

The type collection of *B. plicatella*, as here restricted, comprises four excellent internal molds of ventral valves, one of which is the holotype, three poor ventral exteriors, one poor dorsal exterior, and one good dorsal internal mold. The holotype is a large valve, and only one of the ventral exteriors approaches it in size; the other ventral and dorsal exteriors are much smaller, evidently being immature individuals. The large ventral exterior is the only specimen on which the finer details of the surface ornamentation are preserved.

Possibly two species, or at least varieties, characterized by sulcate and nonsulcate

EXPLANATION OF PLATE 37

- FIGS. 1-5—*Otusia sandbergi* (Winchell). 1, Figured specimen (Mont. 51, pl. 93, fig. 4); ventral exterior, U.S.N.M. 35214a, $\times 4$, loc. 302f. 2, Figured specimen; partly exfoliated dorsal exterior, Mont. T1182a, $\times 3$, loc. 46-3. 3, 4, Figured specimen; interior and exterior of incomplete dorsal valve, showing short brachiophores, Mich. 20806a, $\times 3$, loc. M1-4. 5, Figured specimen; incomplete dorsal internal mold, showing eorthoid notothyrial cavity without cardinal process, Mont. T1182b, $\times 3$, loc. 46-3. Upper Cambrian: Dry Creek shale and Snowy Range formation. (p. 251)
- 6-15—*Ocnerorthis monticola* Bell, n. gen., n. sp. 6, 8, 15, Syntype; posterior, oblique-posterior and exterior views of dorsal valve in which cardinal process is exceptionally developed, Mont. T1174c, $\times 3$, loc. 44-2. 7, 10, Syntype; interior views of incomplete ventral valve, the former tilted so as to show strong dental plates, Mont. T1174a, $\times 4$, loc. 44-2. 11, Exterior view of same valve, Mont. T1174a, $\times 4$, loc. 44-2. 9, Syntype; ventral interior, Mont. T1174d, $\times 3$, loc. 44-2. 12, Syntype; dorsal interior, showing sturdy brachiophores and cardinal process, Mont. T1174b, $\times 3$, loc. 44-2. 13, 14, Syntypes; dorsal exteriors, the former with greatly extended cardinal process, Mont. T1174e-f, $\times 3$, loc. 44-2. Upper Cambrian: Dry Creek shale. (p. 253)
- 16, 17—*Ocnerorthis? iddingsi* (Walcott). 16, Exteriors of adjoining ventral and dorsal valves; ventral valve the holotype (Mon. 51, pl. 91, fig. 3) U.S.N.M. 52340a, dorsal valve a paratype (Mon. 51, pl. 91, fig. 3a) U.S.N.M. 52340b; $\times 3$, loc. 302c. 17, Paratype (Mon. 51, pl. 91, fig. 3b); badly damaged ventral interior, U.S.N.M. 52340c, $\times 3$, loc. 302c. Upper Cambrian: Dry Creek shale. (p. 253)
- 18-25—*Ocnerorthis cooperi* Bell, n. gen., n. sp. 18, 21, Syntype; posterior and interior views of dorsal valve, showing anterior end of strong cardinal process embedded in long median ridge, U.S.N.M. 96802d, $\times 3$, 19, 20, Syntype; dorsal interior and exterior, U.S.N.M. 96802c, $\times 3$, 22, 25, Syntype; ventral exterior and interior, U.S.N.M. 96802a, $\times 3$, 23, 24, Syntype; ventral interior and exterior, the former tilted to show absence of dental plates, U.S.N.M. 96802b, $\times 3$. Upper Cambrian: Snowy Range formation, Torrey Creek, Wind River Range, Wyoming. (p. 252)

ventral valves, are represented in the type lot. Until a more adequate collection of specimens from the type area is available for study, it seems best to leave the species essentially as Walcott presented it.

BILLINGSSELLA RADIATA

Bell, n. sp.

Plate 36, figures 6-13

This species is close to *B. perfecta* but differs in usually being larger and in having a thinner shell, wider and narrower ventral interarea, wider delthyrial angle, shorter deltidium, and more conspicuous costellae. The ventral hinge line is usually wider than, sometimes equal to, and never less than, the width of the valve at the middle; cardinal extremities rectangular or acutely angular to slightly mucronate. Internally, the brachio-phores are longer, thinner, and more oblique than in *B. perfecta*, the notothyrial platform being scarcely discernible. The costellae are more angular, closer together, and more uniformly distributed on the flanks of the valves; on some specimens they resemble plicae, being readily visible on the inner surface of the shell. The thinness of the shell, a consistent character even in large valves, apparently allows no distinct impressions of muscular or pallial marks.

Dimensions (mm.)

	Length	Width	Hinge width	L/W
Ventral valves:				
Mont. T1171b...	7.6	8.2	8.8	0.93
Mont. T1171c...	8.3	9.0	9.2	0.92
Dorsal valves:				
Mont. T1171e...	8.5	10.8	9.5	0.78
Mont. T1171f...	7.7	10.3	9.8	0.77

Syntypes, Mont. T1171a-f; figured specimen: Mich. 20802a.

Horizon and locality.—Upper Cambrian. Dry Creek shale: 44-2, Crowfoot Ridge. Snowy Range formation: M1-4, Beartooth Butte; M2-1, Republic Mt.

Discussion.—Although *Billingsella radiata* is typically larger than *B. perfecta*, the thinness of the valves caused a high mortality during preparation. Consequently only the thicker cardinal portions of the valves are usually preserved. This species resembles *B. exasperata* in having a narrow ventral interarea, but differs distinctly from it in outline, convexity, and radial ornamentation.

BILLINGSSELLA WEEDI (Walcott)

Plate 36, figures 3-5

Huenella? weedi WALCOTT, 1924, Smithsonian Misc. Coll., vol. 67, no. 9, p. 522, pl. 120, figs. 5, 7, 8.

The type specimens of this species are associated with numerous specimens of *Huenella abnormis* (Walcott) on two small slabs of limestone from the north slope of Crowfoot Ridge. They comprise two somewhat weathered ventral exteriors, one broken dorsal exterior, and several fragments of ventral and dorsal valves. On the reverse side of one slab is an internal mold of the apical portion of a ventral valve, which evidently was not noted by Walcott.

Although the specimens of *Billingsella weedi* are inadequate for a complete description, they appear to be sufficiently distinct from other species in Montana and Wyoming to justify retention of Walcott's name. The following emendation of Walcott's very meager description is based only on the types of the species, which at present is known only from the type locality.

Ventral valve: Outline probably subquadrate or elongate subrectangular; hinge probably slightly less than width of valve at middle; posterior margins straight; apical angle nearly 180°; umbo swollen, posterolateral flanks flattened to concave; profile moderately convex, with greatest height slightly posterior to middle; surface paucicostellate, broad intercostellate spaces closely parvicostellate; no axial fold or furrows; interarea very wide in proportion to length, flat, slightly apsacline; pseudospondylium high; delthyrium and deltidium, muscular and vascular impressions not visible.

Dorsal valve: Apparently subquadrate; hinge shorter than width of valve at middle; profile nearly flat; interarea vertical, short; notothyrium open; cardinal process present; surface paucicostellate, not over three or four costellae on each flank; intercostellate spaces closely parvicostellate; character of sulcus unknown but apparently shallow.

Dimensions (mm.)

	Length	Width	Hinge width	L/W
Ventral valve:				
U.S.N.M. 69798a	8.7?	8.7?	?	1.0
Dorsal valve:				
U.S.N.M. 69798c	6.0	8.3?	7.0	0.72

Syntypes, U.S.N.M. 69798 a-c; hypotype, U.S.N.M. 69798d.

Horizon and locality.—Dry Creek shale: U.S.N.M. loc. 302g, north slope of Crow-foot Ridge.

Discussion.—*Billingsella weedi* most closely resembles *B. exasperata*, but differs from it in being elongate subrectangular in ventral outline and in having a different ornamentation; from *B. perfecta* it differs in being more convex and differently ornamented and in lacking a ventral fold; from *B. plicatella* it differs in being much less convex.

Genus OTUSIA Walcott, 1905

OTUSIA SANDBERGI (Winchell)

Plate 37, figures 1–5

Orthis sandbergi WINCHELL, 1886. Geol. and Nat. History Survey Minnesota, 14th Ann. Rept., p. 318, pl. 2, figs. 8, 9.

Orthis? sandbergi WALCOTT, 1899, U. S. Geol. Survey, Mon. 32, pt. 2, p. 452, pl. 61, figs. 2, 2a–d.

Billingsella (Otusia) sandbergi WALCOTT, 1905, U. S. Nat. Mus., Proc., vol. 28, p. 246.

Otusia sandbergi WALCOTT, 1912, U. S. Geol. Survey, Mon. 51, p. 769, pl. 93, figs. 4, 4a–d.

This species is poorly represented in the writer's collections by a few dorsal valves, which closely resemble specimens from near the type locality in Minnesota. Walcott's (1912, p. 769) definition of the species apparently was based primarily on specimens from Yellowstone Park that, in the writer's opinion may belong to *Billingsella* rather than to *Otusia*. However, because comparison could not be made directly with the types, and because the specimens from Montana give little information of the internal morphology, no change is made in present designations. It should be pointed out that the writer's specimens, which in external appearance resemble individuals of *O. sandbergi* from the Upper Mississippi Valley more closely than do those from Yellowstone Park, possess a notothyrial cavity (pl. 37, fig. 5) like that in *Eoorthis remnicha* (Winchell), whereas the specimens from Yellowstone Park have a strong cardinal process like that in *Billingsella*.

Figured specimens.—Mont. T1182a–b; Mich. 20806a; U.S.N.M. 35214a.

Horizon and locality.—Upper Cambrian. Dry Creek shale: 46-3, Nixon Gulch; U.S.-N.M. loc. 302f, Elk Pass, Yellowstone Park.

Snowy Range formation: M1-4, Beartooth Butte.

Genus OCNERORTHIS Bell, n. gen.

(Gr. *δκνῆρος*, hesitating; *Orthis*)

Outline subquadrate; profile unequally bi-convex to planoconvex; ventral interarea longer than dorsal; anterior commissure sulcate; surface costellate.

Ventral valve: Interarea concave, nearly orthocline in the genotype, strongly apsacline in *O. monticola*; beak incurved; delthyrium open except for small callosity at apex. Delthyrial cavity deep; teeth strong, oblique or nearly horizontal; dental plates absent in the genotype, present in *O. monticola*; musculature as in *Billingsella* and *Eoorthis*; pallial trunks subparallel, straight.

Dorsal valve: Interarea strongly anacline to hypercline; notothyrium open. Brachio-phores as in *Billingsella* and *Eoorthis*; notothyrial platform strongly developed, extending anteriorly as a low ridge, which widens and often thickens near the margin; cardinal process short, stout, orthoid; musculature as in *Billingsella* and *Eoorthis*.

Genotype, *Ocnerorthis cooperi* Bell, n. sp.

Distinguishing characters.—*Ocnerorthis* is characterized by its strongly convex, eorthoid ventral valve, flat or slightly convex dorsal valve, a strong dorsal ridge, which widens anteriorly and extends nearly to the margin, and a costellate or parvicostellate surface.

Discussion.—An anomalous combination of characters is exhibited by *Ocnerorthis*. The ventral valve is distinctly eorthoid in its form, particularly in *O. monticola*, in which the resemblance is carried to an extreme by the presence of well-developed dental plates and a strongly apsacline interarea. In contrast, the dorsal valve, with its stout brachio-phores and high notothyrial platform anterior to the strong cardinal process, bears a close resemblance to *Billingsella*. Young dorsal valves of *Ocnerorthis* and *Billingsella* are almost indistinguishable, except for the broad median elevation extending nearly to the anterior margin in the former. These hybrid relationships, together with wide specific fluctuations, as indicated by variation in the cardinal extremities, length of hingeline, and presence or absence of dental plates, suggests an unstable organism

distantly related to both *Billingsella* and *Eoorthis*.

Two genera may be represented by *O. cooperi* and *O. monticola*. The similarity of the dorsal valves of these species certainly indicates a family, though perhaps not necessarily a generic relationship. Each species is known with certainty from a single locality, and although some specimens are very well preserved, they are few in number. Because the material for study is so limited, and the systematic significance of dental plates among these primitive orthids is not understood, it seems best to include both species in one genus rather than to establish two monotypic genera. The generic diagnosis has been prepared principally from the genotype, *O. cooperi*.

OCNERORTHIS COOPERI Bell, n. sp.

Plate 37, figures 18–25

Outline subquadrate or slightly elongate ovate; cardinal extremities rounded or slightly mucronate; hinge equal to or less than width of shell at middle; anterior commissure sulcate, sometimes slightly emarginate; profile planoconvex, greatest height being at middle of ventral valve; surface coarsely and evenly fascicostellate in ventral valve, fascicostellate and parvicostellate in dorsal valve.

Ventral valve: Posterior margins slightly concave, apical angle 135° – 140° ; interarea longer than that of dorsal valve, concave, orthocline or slightly apsacline; beak incurved; delthyrium open; surface coarsely and evenly fascicostellate. Delthyrial cavity wide and deep, with subtriangular apical callosity like that in *Billingsella perfecta*; teeth flat, elongate, nearly horizontal, continuous with palintrope; dental plates absent; adductor track broad, having subparallel sides, and extending past diductor scars; pallial trunks broad, straight, diverging slightly from their origin in the diductor scars, and reaching nearly to margin of valve.

Dorsal valve: Outline obtusely subquadrate; posterior margin straight; anterior margin emarginate; apex minute, marginal; sulcus increases in depth from apex to margin, its abrupt sides diverging at about 30° ; interarea very short, anacline; notothyrium open; flanks of valve fascicostellate; sulcus

parvicostellate, with a few widely separated costellae present anteriorly in some specimens. Notothyrial cavity shallow; brachio-phores linear, divergent, nearly parallel to cardinal margin, and supported by two low ridges of callus, which converge and fuse at anterior end of cardinal process into a single low rounded elevation; elevation widens and thickens anteriorly, ending abruptly near margin of valve; cardinal process a short vertical plate, embedded anteriorly in the low median ridge.

Dimensions (mm.)

	Length	Width	Hinge width	L/W
Ventral valves:				
U.S.N.M. 96802a	10.0	9.6	8.0	1.04
U.S.N.M. 96802b	9.2	9.8	8.4	0.94
Dorsal valves:				
U.S.N.M. 96802c	6.7	9.8	9.0	0.68
U.S.N.M. 96802d	5.9	8.0	6.1	0.74

Syntypes, U.S.N.M. 96802a–d.

Horizon and locality.—Upper Cambrian. Snowy Range formation: Torrey Creek, Wind River Range, Wyoming.

Distinguishing characters.—*Ocnerorthis cooperi* is characterized by its lack of dental plates, its concave, nearly orthocline ventral interarea, and the conspicuous elevation and widening of the median dorsal ridge.

Discussion.—This species differs from *O. monticola* in its lack of dental plates, and in the orientation of the ventral interarea.

The subtriangular deposit of callus at the apex of the delthyrial cavity seems identical in form and position to that present in *Billingsella* (Ulrich and Cooper, 1938, p. 72). The callus, which extends anteriorly as a short septum, evidently strengthened the apex of the pseudodeltidium in *Billingsella*, but its function in *Ocnerorthis*, except perhaps as a foundation for pedicle attachment, is not apparent.

A pair of conspicuous callosities or scars occur at the anterior end of the median ridge in one dorsal valve (pl. 37, fig. 19). If they are muscular scars, which appears improbable, they are relatively farther forward than in any species of brachiopod with which the writer is familiar. In the same dorsal valve are a pair of short, narrow arcuate ridges, convex toward the cardinal extremities and extending anterolaterally from a position abutting the terminal ends

of the brachiophores. They may represent pallial trunks, but nothing similar is known among Cambrian orthoids.

OCNERORTHIS? IDDINGSI (Walcott)

Plate 37, figures 16, 17

Orthis? remnicha Winchell. WALCOTT (part), 1899, U. S. Geol. Survey, Mon. 32, pt. 2, pl. 62, figs. 1a-b.

Orthis (Plectorthis) iddingsi WALCOTT, 1905, U. S. Nat. Mus., Proc., vol. 28, p. 264.

Eoorthis iddingsi WALCOTT, 1912, U. S. Geol. Survey, Mon. 51, p. 780, pl. 91, figs. 3, 3a-b.

The specimens from the type locality are very poorly preserved, but the form of the valves, and the surface ornamentation seem to place the species in *Ocnerorthis*. It seems most likely that the specimens are conspecific with *O. monticola*, but without a knowledge of either the ventral or dorsal internal structure, an assignment to *Ocnerorthis* cannot be made with any degree of certainty. Consequently, it seems best to restrict the name *O. iddingsi* to the type specimens.

Holotype, U.S.N.M. 52340a; paratypes, U.S.N.M. 52340b-c.

Horizon and locality.—Upper Cambrian. Dry Creek shale; U.S.N.M. loc. 302c, south side of Gallatin Valley, Yellowstone Park, Wyoming.

OCNERORTHIS MONTICOLA Bell, n. sp.

Plate 37, figures 6-15

Outline obtusely subquadrate; cardinal extremities rounded or obtusely angular; hinge less than width of shell at middle; anterior commissure rectimarginate or slightly sulcate; profile unequally biconvex, almost planoconvex, greatest height being at middle of ventral valve; ventral interarea longer than dorsal; surface parvicostellate.

Ventral valve: Posterior margins slightly concave; apical angle about 140° ; interarea concave, strongly apsacline; beak incurved; delthyrium open except for very small callosity in apex; surface evenly parvicostellate. Delthyrial cavity deep; dental plates strong, receding, converging slightly and fusing with floor of valve to form a callosity or pseudospondylium, on which adductor scars are elevated; teeth short, roughly triangular in cross section; adductor track narrow, with slightly diverging sides, projecting beyond diductor scars; pallial trunks wide, slightly divergent.

Dorsal valve: Outline subquadrate to ovate; posterior margin straight, equal to or less than width of valve at middle; interarea anacline or hypercline; cardinal extremities rounded or obtusely angular; lateral and anterior margins evenly rounded; sulcus usually present, shallow, with gently sloping sides; surface rather evenly costellate, the costellae on margins of sulcus slightly stronger. Notothyrial cavity shallow; brachiophores short, very stout, cupped on posterolateral margins to form dental sockets and supported by two low ridges of callus, which converge and fuse at anterior end of cardinal process into a single low, broad, rounded elevation; elevation widens slightly and disappears near margin of valve; cardinal process stout, vertical, its anterior end embedded in callus of median ridge and often projecting posteriorly beyond margin of valve.

Dimensions (mm.)

	Length	Width	Hinge width	L/W
Ventral valve:				
Mont. T1174d...	8.5	8.8	8.3	0.97
Dorsal valves:				
Mont. T1174b...	8.2	10.7	9.6	0.77
Mont. T1174f...	7.5	9.5	7.6	0.79

Syntypes, Mont. T1174a-f.

Horizon and locality.—Upper Cambrian. Dry Creek shale; 44-2, Crowfoot Ridge.

Distinguishing characters.—*Ocnerorthis monticola* is characterized by its stout receding dental plates, concave and strongly apsacline ventral interarea, and stout cupped brachiophores.

Discussion.—This species differs from *O. cooperi* most obviously in the presence of dental plates, and in the orientation of the ventral interarea.

The very apex of the delthyrium in one silicified ventral valve (pl. 37, figs. 7, 10) is filled with callus. The deposit is limited to the apex of the valve, not extending anteriorly as in *O. cooperi*.

Two unsilicified dorsal valves (pl. 37, figs. 6, 8, 13, 15) exhibit a remarkable development of the cardinal process. So far as can be determined, the excessive extension of the structure posteriorly is not a secondary feature.

Only one dorsal valve (pl. 37, fig. 12) shows what may be a part of the muscular

pattern. A pair of elongate scars, slightly divergent anteriorly, border the median ridge about the middle of the valve.

Genus EOORTHIS Walcott, 1908
EOORTHIS REMNICA (Winchell)
Plate 36, figures 14-23

Orthis remnica WINCHELL, 1886, Minnesota Geol. and Nat. History Survey, 14th Ann. Rept., p. 317, pl. 2, fig. 7.

Eoorthis remnica WALCOTT, 1912, U. S. Geol. Survey, Mon. 51, p. 786, pl. 91, figs. 1, 1a-s, pl. 92, figs. 2, 2a-d, 3, 3a-e; SCHUCHERT and COOPER, 1932, Peabody Mus. Nat. History, Mem., vol. 4, pt. 1, pl. 1, fig. 23; Ulrich and Cooper, 1938, Geol. Soc. America, Special Paper 13, pl. 9E, figs. 16-22.

This is the only species of *Eoorthis* in the collections from Montana. An appreciable variation occurs in the species, especially in the contour of the valves and in the form of the ventral muscular area and cardinal process. None of these variations are sufficiently constant, however, to warrant a varietal assignment to them. Perhaps a statistical treatment of larger collections may lead to a finer definition of the species.

Apparently *Eoorthis remnica* everywhere occurs associated with species of *Billingsella*, the *Eoorthis* and *Billingsella* subzones of the upper Mississippi Valley province not being recognized in Montana.

Figured specimens, Mont. T1173a-e, T1175a; Mich. 20800a.

Horizon and locality.—Upper Cambrian. Dry Creek shale: 39-1 (?), Yogo Gulch 44-2, Crowfoot Ridge; 46-3, Nixon Gulch; U.S.N.M. localities 4r, Mount Delano; 151, 152, Bridger Range; 153a, 154, 158, near Hillsdale; 302b (2), 302f, Yellowstone Park; 302n, lower Gallatin Valley. Snowy Range formation; M1-4, Beartooth Butte; M2-1, Republic Mt.

Genus HUENELLA Walcott, 1908
HUENELLA ABNORMIS (Walcott)
Plate 36, figures 1-3

Syntrophia abnormis WALCOTT, 1905, U. S. Nat. Mus., Proc., vol. 28, p. 289.

Huenella abnormis WALCOTT, 1912, U. S. Geol. Survey, Mon. 51, p. 805, pl. 103, figs. 2, 2a-m; SCHUCHERT and COOPER, 1932, Peabody Mus. Nat. History, Mem., vol. 4, pt. 1, text figs. 24a-e, p. 160.

Huenella texana (Walcott). WALCOTT, 1924, Smithsonian Misc. Coll., vol. 67, no. 9, pl. 120, figs. 4-8; ULRICH and COOPER, 1938, Geol. Soc. America, Special Paper 13, pl. 41D, figs. 20, 29.

Though Walcott (1912, p. 806) believed that this species and *H. texana* intergraded, he recognized two species, because most of the individuals from Montana differ from those from Texas. The present study substantiates Walcott's conclusion. *H. abnormis* is typified by a sharply and strongly folded dorsal valve in which the fold has three costae, the outer two diverging from the apex, and the middle one being implanted anterior to the apex. This type of valve predominates, but some valves show all gradations from a plicate to a smooth fold. The ventral valve is deeply sulcate, the sulcus of most specimens smooth, and that of a few individuals with as many as four narrow low costae. Except for costae on the fold and sulcus, the valves appear to be smooth, with faint concentric growth lamellae. The typical form of *H. texana* has a lower fold and shallower sulcus than *H. abnormis*; in *H. texana* the fold, sulcus, and adjacent flanks of the valves bear low costae.

Holotype, U.S.N.M. 52462b; paratype, U.S.N.M. 52462e.

Horizon and locality.—Upper Cambrian. Dry Creek shale: 46-3, Nixon Gulch; U.S.N.M. localities 4j, head of Deep Creek and 302g, Crowfoot Ridge, both in Yellowstone Park; 153, 157, 158, all near Hillsdale.

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